Blood, sweat and tears:

The intra- and interindividual function of adult emotional weeping

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For my parents Andrea and Roger Baker

Abstract

Crying accompanies a person's most important life moments, it is a new-born's primary mode of communication, and is found in all cultures at every stage of a person's life. Crying is thought to not only communicate emotions, but to act as a cathartic mechanism that reduces physiological arousal and improves mood. Whilst crying involves different behaviours, it is the visible shedding of tears, known as weeping, which is considered the main component. Despite weeping being the main behaviour, it has received little focus in the crying literature, primarily, due to the difficulty in inducing weeping in a controlled environment. The overarching aim of this program of research is to investigate the role of weeping on the intraindividual and interindividual functions of crying.

In **Chapter two**, we reviewed the emotion induction literature and demonstrate how heart rate responses are dictated by how we induce emotions and not which emotion we induce. The results of this large review are consistent with predictions made by the intake-rejection hypothesis taken from the classic cognitive psychophysiology literature. The intake-rejection hypothesis suggests attending to external stimuli reduces heart rate, whereas, turning our attention to internal cognition, such as memory, increases heart rate. We found heart rate responses in emotion inductions were a product of attention and not affect. We suggest the primary reason for our findings is because laboratory induced emotions are mild. Moving forward, we propose developing induction procedures that will increase the intensity of emotions, this is especially important for laboratory induced weeping where intense emotions are a necessity.

In **Chapters three and four**, we used an idiographic induction technique to induce weeping in the laboratory. We measured multiple psychological and physiological indices including facial thermography, heart rate, respiration rate, skin

conductance and subjective affect. In **Chapter three**, we found episodes of weeping were associated with a large increase in facial temperatures and increased negative affect compared to non-weepers. These changes were in the absence of any major cardiorespiratory or electrodermal responses. In **Chapter four**, we showed how the suppression of tears led to a physiological stability, whilst, weeping was again associated with large facial temperature increase. The thermal response was influenced by increased sympathetic nervous system activity and was specifically tied to weeping and not underlying affect. Overall, we found no evidence weeping led to any psychophysiological restoration.

In **Chapter five**, we explored the interindividual function of weeping and why tears signal sadness despite accompanying a range of both positive and negative emotions. Context is an important influence of how we perceive the emotion of others. The situational cues provided by setting a context can alter the way emotional expressions are perceived, the Kuleshov effect is a film editing technique creates meaning through the interaction of contextual scenes and actor expressions. We utilised the Kuleshov effect, to add emotional context to videos of weeping targets. We found that weeping was associated with increased attributions of both sadness *and* the contextual emotion. This suggests the context is having a top-down effect on the judge's perceptions of emotions; however, this effect was present in some but not all judges.

Overall, this program of research shows not only the importance of weeping to our understanding of crying, but the importance of *weeping in context*. We suggest that weeping should be considered primarily as a social signal opposed to having any immediate benefit to the crier. Secondly, by using an idiographic induction technique we were able to generate strong emotions in the laboratory that may help inform the wider debates in the emotion literature.

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Abbreviations

ANOVA: Analysis of variance

ANS: Autonomic nervous system

ASH: Autonomic specificity hypothesis

AU: Action units

BET: Basic emotion Theory

BEQ: Berkley Expressivity Questionnaire

BEV: Behavioural ecology view of facial displays

CEQ: Creative Experiences Questionnaire

ECG: Electrocardiogram

FACS: Facial action coding system

FPA: Focal plane array

HR: Heart rate

HRV: Heart rate variability

IBI: Inter-beat interval

LWIR: Longwave infrared

MANOVA: Multivariate analysis of variance

PNS: Parasympathetic nervous system

rMSSD: Root mean square of the successive differences

ROI: Region of interest

RR: Respiration rate

RSA: Respiratory sinus arrhythmia

SCL: Skin conductance level

SDNN: Standard deviation of the IBI of normal sinus beats

SNS: Sympathetic nervous system

Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

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List of Figures and Tables

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Chapter 1: General Introduction

1.1 Introduction

Emotional crying is a potentially powerful and compelling expression that is primarily characterised by the shedding of tears from the lacrimal apparatus, known as weeping (Vingerhoets et al., 2000; Vingerhoets & Bylsma, 2016; Vingerhoets & Cornelius, 2001). Crying is unique to humans and is found across all cultures and in all stages of life (Bylsma et al., 2019; Gračanin, Bylsma, et al., 2018). Crying in infants can be an acoustic signal used to signal distress and elicit support, however, crying in adults is a more flexible visual signal (Gračanin, Bylsma, et al., 2018; Rottenberg & Vingerhoets, 2012; Vingerhoets & Cornelius, 2001). Tears are thought to not only communicate emotions but to improve the criers mood by releasing 'emotional pressure' (Bylsma et al., 2008; Gračanin et al., 2015). Despite crying being a behaviour the accompanies the most significant moments in a person's life, it has received relatively little focus in the scientific literature. The literature is also misrepresentative because crying is inherently difficult to induce in a controlled environment, therefore, most empirical studies on crying do not always involve weeping. The following review of the literature will highlight some of the wider debates in the emotion literature, discuss the current literature on adult crying and argue that weeping should be the principal focus for empirical studies if we are to fully understand emotional crying.

1.2 Theories of Emotion

Whilst emotions are a fundamental part of human and animal psychology, there is very little agreement on the what emotions actually are (Gross & Barrett, 2011; Lench et al., 2013; Lindquist et al., 2013). This problem agreeing on the very nature of emotions has led to difficulties drawing firm conclusions from any of the empirical data (Barrett, 2006; Scarantino, 2012). There is a consensus that emotions are responses to stimuli, both real and imagined, that are short-lived. Emotions are accompanied by changes in behaviour, cognition and physiology which originated both to motivate and to aid an organism to complete actions which benefit survival (Gross & Barrett, 2011; Izard, 2007; Lindquist et al., 2013). One central disagreement in the emotion literature is whether emotions are biologically discrete units (referred to as Basic Emotion Theory [BET]) or psychologically constructed (Gross & Barrett, 2011). Proponents of the BET consider emotions to have strong biological ties with clear differences between each emotion, sadness is phenomenologically different from fear and involves emotion specific physiological responses and emotion specific neurocircuitry (Buck, 1994; Lench et al., 2011; Quigley & Barrett, 2014). This position is challenged by the psychological constructionists who view emotions as rough categories that are 'soft' built through experience, emotions are made and not *just* experienced by organism (Barrett, 2014; Lindquist et al., 2012; Quigley & Barrett, 2014). They suggest a learning process shapes the experience of emotion. Through language we learn to categorise certain situations as emotional, and any physiological responses reflect an interaction of underlying components such as arousal, attention and approach tendencies (Barrett, 2006, 2014; Russell & Barrett, 1999). They predict socio-cultural differences and physiological responses to vary between people and contexts (Siegel et al., 2018). Whilst the constructionist theories of emotion have gained traction in recent years (Lindquist, 2013), results from the empirical literature do not provide consistent support for either position.

There are areas in which there is some consensus, both viewpoints consider the boundaries between emotions to be 'fuzzy' and not fixed. There appears to be smooth gradients both *within* and *between* emotional categories which gives rise to mixed emotional states or subjective feelings that are transitional between emotional categories (Cowen & Keltner, 2017; Siegel et al., 2018). There is also consensus that instances of a specific emotion can vary greatly depending on contextual factors. For instance, the subjective feelings of fear when an arachnophobic encounters a spider is modulated by multiple factors such as, proximity and size of the spider, ability to escape the situation, and whether the social context affords them interpersonal protection (Scarantino, 2017). Finally, there is agreement that emotions are complex and situationally dependent. The complex nature of emotion allows for flexibility in response adjusted to the context in which the emotion is experienced. In this sense, variability in emotional experience should be expected both *between* people and *between* events within the same person (Scarantino, 2012).

1.2.1 Emotions and Physiology

Changes in physiology are considered a key part of the emotional experience (Gross & Barrett, 2011). However, the precise relationship between emotions and physiology is less well understood (Kreibig, 2010; Siegel et al., 2018). Emotions and physiology are considered so intertwined that in some theories of emotion the physiological response *is* the emotion (Cannon, 1987; James, 1894; Lang, 1994). Research on the physiological response of emotions is often focused on the autonomic nervous system (ANS) and the impact of both the sympathetic and parasympathetic branches. The sympathetic nervous system (SNS) is often referred to as the flight/fight mechanism and can be measured through electrodermal activity of palmer sites on the hands and feet, or by measuring the pre-ejection period of each heart beat (Cacioppo et al., 1993; Kreibig, 2010; Smith et al., 2000). The parasympathetic nervous system (PNS) is considered the restorative branch of the ANS often referred to as the ‘rest and digest’ mechanism (Cacioppo et al., 1993; Kreibig, 2010; Porges, 2001). It can be measured through high-frequency heart rate variability and respiration rates; these are often combined to create a measure of respiratory sinus arrythmia (Berntson et al., 1997). To disentangle the inputs of the SNS and PNS a range of measurements are combined which traditionally include heart rate, blood pressure, electrodermal activity, and respiration rates (Kreibig, 2010). Classically, BET theorists suggest the combination of physiological responses is unique to each emotion (Kreibig, 2010). In contrast constructionists view the combination as unique to the person and reflects a population of responses based on underlying factors such as arousal, stress and attentional demands (Siegel et al., 2018). The goal of much of the past research using physiology has been to find an emotional 'fingerprint', a set of emotional responses specific to each emotional category. To date, no emotional fingerprints have been clearly identified.

There have been four prominent meta-analyses (Larsen et al., 2008; Lench et al., 2011; Siegel et al., 2018; Stemmler, 2004) and one qualitative review (Kreibig, 2010) examining the specificity of ANS responses to emotion. The strongest evidence for differentiation of emotions can be found between anger and fear, however, even this evidence is not unequivocal (Lench et al., 2011; Stemmler, 2004). Similarly, the qualitative review found a degree of specificity in the direction of physiological response although failed to identify clear boundaries between emotional categories (Kreibig, 2010). The most recent meta-analysis directly tested the consistency of response and reported a large variance *within* each emotion and considerable similarities *between* different emotions (Siegel et al., 2018). Overall, there is a remarkable lack of consistency within each emotional category. For instance, inductions of fear sometimes lead to increases in heart rate whilst in other studies we see decreases. This level of inconsistency occurs most prominently in heart rate, but we see inconsistencies across all ANS measurements and for all emotional categories. There is a consensus that a 'fingerprint' is unlikely to be found for emotional categories (Scarantino, 2017), but to further our understanding of the

ANS responses during emotion it seems important to identify what factors do explain the variance found across different studies.

1.2.2 Expressions of Emotion

Emotions are inherently social, therefore a critical part of understanding emotions is how they are expressed and how these expressions are perceived by observers (Fernández-Dols & Russell, 2017; Fridlund, 2014). The primary canvas for expressing emotions is the face, although behaviour, non-verbal vocalisations, body language and decision making can often reveal a lot about underlying affective states (Boddeker & Stemmler, 2000; Kugler et al., 2012; Lerner & Tiedens, 2006; Lima et al., 2013). Facial expressions involve the contraction of groups of muscles which alter the shape and position of facial features such as the eyes, nose and mouth (Ekman & Friesen, 1971). Despite a countless range of possible combinations, facial muscle contractions are coordinated and produce coordinated expressions that can be decoded by perceivers (Ekman, 1993). For instance, by raising the corners of our mouths we produce a smile, which communicates happiness (Ekman et al., 1990). Furthermore, there are some automatic and explicit indicators of affect found on the face, such as blushing or crying, that have been shown to be extremely powerful social signals (Provine, 2012). Facial expressions and emotional behaviour have rich and in-depth literatures (see Fernández-Dols & Russell, 2017; Fridlund, 2014). The central debate is 'to what degree facial expressions and emotional behaviour reflect underling affect' and 'to what degree are facial expressions and emotional behaviour universal and automatic' (Ekman, 1993; Ekman & Friesen, 1971; Fernández-Dols & Russell, 2017; Fridlund, 2014).

The debate surrounding the role of facial expressions in emotion reflects the wider debate regarding the nature of emotions. BET suggests facial expressions are a direct readout of the underlying emotion of the expresser (Buck, 1994; Ekman, 1993, 2016). They suggest facial expressions are both innate and culturally universal (Ekman & Friesen, 1971) and suggest each emotion has its own fixed and prototypical expression that is integral to the experience. They conclude that the experience of emotion is accompanied by the corresponding expression but that this may be modified or suppressed through cognitive mediation (Matsumoto et al., 2008). Ekman and colleagues popularised the study of facial expressions based on work from Charles Darwin (Darwin, 1872), they famously reported that there is prototypical expressions of emotion found across all cultures (Ekman, 1993; Ekman & Friesen, 1971; Ekman & Oster, 1979). They adopted the facial action coding system (FACS) from Carl-Herman Hjortsö (Hjortsjö, 1969) which quantifies facial muscles into action units (AUs). Trained FACS coders report the intensity of each AU muscle contraction alongside the temporal dynamics of each expression (Cohn et al., 2007). FACS is considered the gold standard in quantifying facial movements (Cohn et al., 2007) and has been transferred to non-human animals with chimpanzees (Vick et al., 2007), dogs (Waller, Peirce, et al., 2013) and horses (Wathan et al., 2015) among the species to have their facial muscles converted to AUs.

The degree to which specific combinations of AUs are a direct readout of underlying emotion has been strongly criticised by the Behavioural Ecology View of Facial Displays ([BEV] Crivelli & Fridlund, 2019; Fridlund, 2014). The BEV states that emotional expressions do not exist in social isolation and they can only be understood from an interpersonal perspective (Fernández-Dols & Russell, 2017; Fridlund, 2014). Facial expressions are flexible and learnt, they do not reflect the expressers underlying emotions but reflect the expressers social goals (Crivelli & Fridlund, 2018). For instance, a smile doesn't tell us how happy someone is but communicates the expresser's wishes for a continuation of the current situation (Crivelli & Fridlund, 2019). BEV theorists view facial expressions as purposeful and active during interpersonal communication compared to a more passive view taken by BET theorists. Despite the current disagreement on the relationship between expressions and emotions, there is little doubt that the face is a critical platform for the transmission of affective information.

Facial expressions are not the only way emotions are communicated, emotions also assert their influence over our actions and behaviours (Gross & Barrett, 2011). These behaviours can also be prototypical and are easily decoded by observers (Clarke et al., 2005; Wallbott, 1998). Body movements such as a clenched fist whilst angry, are decoded and used to infer underlying affect. Whilst facial expressions are communicative, emotional behaviours primarily serve to prepare an organism to negotiate the emotion inducing situation. The clenched fist of the angry person is linked to being prepared to fight, which is linked to the goal of removing the source of their anger (Aviezer et al., 2008; Boddeker & Stemmler, 2000). However, clenched fists are not restricted to episodes of anger, celebrations in sports often involve a clenched fist (Tops & De Jong, 2006). It is also true that a fist can be clenched when someone is experiencing no emotion at all. When somebody clenches their fist, we do not know whether this was emotional in origin. This is not true of all emotional behaviours, there are many behaviours associated with emotion that are unconscious and considered more alike to physiological responses than emotional expressions. These include blushing and, the focus of this thesis, weeping.

1.3 Human Crying

Crying is a secretomotor phenomenon which involves a range of behaviours but is primarily characterised by weeping (Vingerhoets et al., 2000). Weeping is the shedding of tears from the lacrimal apparatus (Bylsma et al., 2019; Vingerhoets et al., 2000). Crying episodes may also include facial expressions, vocalisations and spasmodic breathing; known as sobbing (Gračanin et al., 2014; Vingerhoets, 2013).

Crying can therefore be thought of an ‘umbrella’ term for a cluster of behaviours of which may be present in different intensities (Gračanin et al., 2014, 2015). For instance, the majority of episodes of adult crying include weeping but with no vocalisations (Vingerhoets & Cornelius, 2001), whilst infant crying is often characterised by loud vocalisations and contorted facial expressions but with the absence of weeping (Vingerhoets, 2013; Vingerhoets & Cornelius, 2001). Crying episodes may include a range of behaviours, such as sobbing, vocalisations and facial expressions, but it is weeping that is considered the main behaviour in the crying response (Gračanin, Bylsma, et al., 2018; Vingerhoets, 2013).

Crying in infants appears to share form and function with the distress calls of non-human animals. Infant crying episodes are characteristically loud, do not include weeping, and are primarily used to elicit support from caregivers (Bylsma et al., 2019; Gračanin, Bylsma, et al., 2018; Vingerhoets, 2013; Vingerhoets & Cornelius, 2001). Crying typically goes through ontological changes during a lifetime including the frequency and antecedents (Gračanin, Bylsma, et al., 2018; Vingerhoets & Cornelius, 2001). Crying in infants can be an important survival mechanism which develops into an important attachment behaviour (Hendriks, Nelson, et al., 2008). For adults, crying becomes an important social signal hypothesised to transmit affective signals and solicit emotional support (Hendriks, Croon, et al., 2008; Hendriks & Vingerhoets, 2006; Provine et al., 2009; Simons et al., 2013).

1.3.1 The Neurobiology of Crying

All terrestrial animals produce basal tears which bathe and protect the ocular surface (Bylsma et al., 2019; Gračanin, Bylsma, et al., 2018). Tears consist of water, proteins and electrolytes and have strong antibacterial properties, with lysozyme and immunoglobulin A found in high quantities (Bylsma et al., 2019). Basal tears are produced in the accessory lacrimal gland under the lower eyelid. During waking hours basal tears are continuously secreted at a rate of 1µl per minute which adjusts for natural evaporation and any excess drains through the lacrimal puncta situated in the corner of the eyes (Bylsma et al., 2019).

All terrestrial animals, except snakes and some amphibians, produce reflex lacrimation if the ocular surface is agitated by a physical irritant (Bylsma et al., 2019). Reflex tears, as well as emotional tears, are produced in the lacrimal apparatus which are positioned above the eye on the outer side of the orbit (Bylsma et al., 2019; Vingerhoets & Cornelius, 2001). The secretion cells in the lacrimal gland are primarily innervated by the PNS through the sphenopalatine ganglion, however, blood vessels in the lacrimal gland receive efferent sympathetic input from the superior cervical ganglion (Bylsma et al., 2019). Stimulation of the parasympathetic nerve increases tear secretion whereas stimulation of the sympathetic input effects blood supply to the lacrimal gland but has little effect on tear secretion (Vingerhoets & Cornelius, 2001). Reflex lacrimation occurs when a physical irritant stimulates the sensory nerves of the cornea which transmit to the lacrimal nucleus through the trigeminal nerve. This is then relayed to the efferent parasympathetic nerves which stimulate tear secretion (Bylsma et al., 2019).

Only humans seem to produce emotional tears (Gračanin, Bylsma, et al., 2018). The evolution of emotional tears has been suggested to be part of the prolonged development stage and hyper-sociality of humans (Gračanin, Bylsma, et al., 2018). It is suggested that both factors created the necessary evolutionary pressures where an honest signal of emotional responding was a selective advantage. Furthermore, the increase in facial musculature during evolution, especially around the eye, seems to provide the sufficient mechanical force on the lacrimal gland during intense contractions of the *Orbicularis oculi* to produce tears (Bylsma et al., 2019; Gračanin, Bylsma, et al., 2018; Vingerhoets, 2013). The visual signal of tears probably held a large selective advantage over an acoustic signal. Acoustic signals are non-directional and broadcast widely, alerting the attention to not only caregivers but to potential predators over large distances. A visual signal can be directed to the appropriate caregiver, without alerting others, but requires a degree of locomotion from the crier (Vingerhoets, 2013).

1.3.2 Developmental Perspectives of Crying

Crying is often the first and only communicative ability of new-born infants (Vingerhoets & Cornelius, 2001). Weeping occurs at around 4-6 weeks, prior to this episodes of crying *are* episodes of wailing (Gračanin, Bylsma, et al., 2018; Rottenberg & Vingerhoets, 2012; Vingerhoets & Bylsma, 2016). Infant crying has been referred to as the 'acoustic umbilical cord' and its primary function is to attract the attention and support of a caregiver (Gustafsson et al., 2013; Ostwald, 1972). Acoustical crying seems to signals the infant's physical distress. Hunger, pain, and tiredness are often the main culprits which induce crying in infants. When the first tears appear there is typically a change in crying behaviours from being a purely acoustic signal to a primarily visual signal (Vingerhoets & Cornelius, 2001). This coincides with improved locomotion from the infant at around one year of age, thus crying changes from an undirected distress call, which attracts attention from everything in the local environment, to a person directed signal. This means that the infant can now choose who crying is aimed at, and it is usually directed towards known caregivers (Vingerhoets & Cornelius, 2001). The infant's use of tears to stimulate a response in the caregiver positions crying as an important mechanism in infant attachment (Hendriks, Nelson, et al., 2008). When infants gain mobility, the presence of strangers tends to become a strong inducer of tears (Vingerhoets & Cornelius, 2001) and this relationship is at the heart of the 'Strange Situation' employed by developmental psychologists as a method to classify infant attachment (Ainsworth & Bell, 1970).

The antecedents of crying typically change over time. Physical distress stops producing tears and is replaced with emotional or social distress. Physical pain remains a strong predictor of crying until adulthood where it sharply diminishes (Vingerhoets & Cornelius, 2001). The frequency and proneness of crying drops around puberty, where episodes of crying become primarily related to the experience of intense emotions and the regulation of crying starts to be strongly influenced by social contexts. Around adolescence we see the first gender based differences which persist throughout a lifetime (Vingerhoets & Cornelius, 2001).

1.3.3 Individual Differences, Personality and Crying

The largest demographic determining factor in adult crying behaviour seems to be gender. Females cry about seven times more often (Sharman, Dingle, Baker, et al., 2019; Vingerhoets & Cornelius, 2001), cry at a wider range events (Denckla et al., 2014; Sharman et al., 2018), suppress crying less (Millings et al., 2016) and report more benefits to crying (Sharman et al., 2018; Sharman, Dingle, Baker, et al., 2019). Crying during sport is one of the only deviant cases, in this respect, males are more likely to cry whilst watching sport than females (MacArthur & Shields, 2015). At least in western cultures, the majority of gender differences are explained by the difference in social display rules for males and females (Van Tilburg et al., 2002). Whilst females are encouraged to show emotions, males are expected to remain composed. This is exaggerated in crying because it is considered a sign of weakness (van de Ven et al., 2017; Zickfeld et al., 2018; Zickfeld & Schubert, 2018). Although there is now a greater appreciation about how using defined gender roles can be problematic in development (Meyer & Gelman, 2016), there are still large differences between males and females in their crying behaviour (Sharman, Dingle, Baker, et al., 2019).

Although gender is the largest determining factor in crying behaviour, there are some other individual differences that have small effects. The personality variables that tend to affect crying behaviour tend to relate to emotional stability and inhibitory control (Vingerhoets & Cornelius, 2001). For instance, neuroticism accounts for differences in crying frequency and proneness, but only in females (Choti et al., 1987; Peter et al., 2001; Rottenberg & Vingerhoets, 2012). Females scoring highly in neuroticism, indicating decreased emotional stability, tend to be more prone to crying and cry more frequently (Peter et al., 2001). There is limited evidence that this relationship exists in males but the low crying rate in males means there is not much variance to account for (Vingerhoets & Cornelius, 2001). Outside of the big five personality dimensions, crying proneness has a small positive relationship with emotional expressivity, fantasy proneness, self-blame and coping factors (Vingerhoets & Cornelius, 2001). The majority of personality variables that have been tested explain a minimal and non-significant amount of variance in crying frequency and proneness. One major reason is that gender and gender roles explain majority of crying behaviour (Becht & Vingerhoets, 2002; Bylsma et al., 2011; Delp & Sackeim, 1987; Sharman, Dingle, Baker, et al., 2019; Vingerhoets & Cornelius, 2001).

1.3.4 Crying Suppression

Adults generally show an excellent ability to regulate when and where they cry (Simons et al., 2013). Colloquially this is called ‘swallowing tears’ (Vingerhoets & Cornelius, 2001) and normally occurs when a cry eliciting situation is in a public setting. Criers generally wait until they are in a private setting before allowing themselves to cry. This is especially prominent in contexts where crying is considered inappropriate, such as the work place (Becker et al., 2017). The main motives for suppressing crying tends to be interindividual; both to avoid attention and maintain reputation (Simons et al., 2013). The interindividual down-regulation seems to stem from the belief that crying is a sign of weakness and may indicate the inability to cope with the current situation.

Mechanisms of emotional suppression can be antecedent or response focused (Gross, 1998; Gross & Levenson, 1993). Antecedent focused suppression attempts to regulate the underlying emotion by reappraising the stimuli to limit the emotion intensity, whilst response focused suppression is controlling the outward expression without modifying the underlying emotion (Gross, 1998). The suppression of crying is primarily a response-focused regulation (Simons et al., 2013; Vingerhoets & Cornelius, 2001). The underlying affective state remains but the outward expression, e.g. tears, is suppressed. The main response-focused regulation strategies are 'putting on a brave face', appearing to be cheerful, or regulating respiration (Simons et al., 2013). Whilst, antecedent focused strategies include changing or reappraising the situation and shifting their attention away from the event; it is very common for people to remove themselves from the situations that induce crying (Simons et al., 2013). Participants rated that they consciously use both antecedent and response focused strategies equally to supress crying (Simons et al., 2013). These findings however are based on retrospective reports and there is currently no data taken at the time of suppression. It should also be noted that certain regulation strategies are context dependent. For instance, if the antecedent of crying were a sad memory, it would be impossible to regulate by changing the situation and would require other strategies such as reappraisal or distraction. Overall, criers select from a wide range of both antecedent and response focused strategies depending on the cry eliciting event.

1.4 Functions of Crying

Crying has been suggested to serve both intra and interindividual functions (Vingerhoets et al., 2000). The intraindividual function relates to the possible mood enhancing benefits the crier receives through the process of crying. These beliefs often stem from psychodynamic theories where crying is considered cathartic (Cornelius, 1981). Crying in this sense acts as a hydraulic release mechanism when emotional pressure builds up (Bylsma et al., 2011; Gračanin et al., 2015; Rottenberg et al., 2008). The interindividual function considers the signal value of tears and how tears elicit responses in observers. Crying functions to elicit support and comfort from others, normally those the crier has a close relationship with (Hendriks & Vingerhoets, 2006; Provine et al., 2009; Vingerhoets et al., 2000). Whilst there has been mixed empirical support that crying improves mood there has been consistent and robust evidence the tears act as powerful social signal which elicits support (Vingerhoets et al., 2000).

1.4.1 Intraindividual Function of Crying

The idea that tears reduce tension and facilitate a return to emotional homeostasis is a popular folk psychology belief (Cornelius, 1981; Sharman et al., 2018; Sharman, Dingle, Baker, et al., 2019; Vingerhoets & Cornelius, 2001). The theory that crying improves mood is propagated by the media, 94% of articles over 140 years promote crying as beneficial to wellbeing (Cornelius, 1981). These beliefs can be traced back to ancient Rome with the poet Ovid often referring to crying as a way of bringing about relief (Gračanin, Bylsma, et al., 2018; Vingerhoets, 2013; Vingerhoets & Cornelius, 2001), however, it was with the psychodynamic theorists where modern beliefs on the beneficial nature of crying gained traction (Gračanin, Bylsma, et al., 2018; Vingerhoets & Cornelius, 2001). In psychodynamic theory, crying as an expression of emotion is cathartic whereas the inhibition of tears is a defence mechanism which increases stress. A hydraulic model is often used which conceptualises crying a release valve. When emotional pressure increases beyond a certain threshold, crying releases the pressure which brings relief (Sadoff, 1966). Crying still plays a role in psychoanalytical therapies and is considered a healthy way to deal with trauma and negative affect (Capps et al., 2015; Knox et al., 2017; Rottenberg et al., 2002).

There has been mixed support for the cathartic intraindividual function of crying. When participants are asked to recollect about crying episodes, around 50% report crying improved their mood (Bylsma et al., 2008, 2011). Crying seems to improve mood for certain types of people and only under certain conditions (Becht & Vingerhoets, 2002; Bylsma et al., 2011). The largest predictors of mood improvement were whether the crier received social support during the crying episode and whether the cry eliciting event was resolved (Bylsma et al., 2011). Both are not strictly intraindividual but instead position crying as a step in a process, by which the eliciting event is either dealt with, or the crier is socially supported through the event. It may be that it is the process of resolution or receiving support that improves mood; crying may facilitate that resolution but may not directly improve mood (Becht & Vingerhoets, 2002; Bylsma et al., 2011; Hendriks et al., 2007). Factors including gender and personality accounted for a negligible proportion of the variance in mood improvement, although respondents with ailments to emotional functioning such as alexithymia and anhedonia where less likely to report mood improvements after crying (Bylsma et al., 2011; Vingerhoets & Cornelius, 2001). Overall, there is some indication that crying can improve mood, but this seem restricted to certain people in certain situations where the cry eliciting event has been resolved.

The mood improving benefits of crying have also been investigated experimentally to assess whether crying reduces psychological and physiological arousal. When crying is induced in the laboratory there is little evidence that crying is associated with mood improvements. Criers rate themselves sadder than non-criers (Gračanin et al., 2015; Gross et al., 1994; Hendriks et al., 2007) and show increased physiological arousal (Gross et al., 1994; Hendriks et al., 2007; Ioannou et al., 2016; Kraemer & Hastrup, 1988; Wassiliwizky et al., 2017).This relationship underlies the paradox of crying (Gračanin et al., 2014). At the time crying is associated with increased negative affect, whilst at a later stage some people report crying improved their mood (Gračanin et al., 2015).

Research into the crying paradox shows there are some mediating variables that may explain this relationship. There is some indication that the time is a critical factor. Mood improvements after crying were found experimentally 90 minutes after crying, compared to the increase negative mood found immediately after crying. It seems then that negative affect increases during the event and slowly improves over the next 90 minutes (Gračanin et al., 2015). The laboratory environment is also remarkably different from the environments people normally cry in; 37% reported being alone during their last crying episode, and 29% when with one other ‘close’ person (Vingerhoets et al., 2001). In laboratories, participants are often tasked with watching a sad film without a close person, which is important given that presence of social support is a key factor when episodes of crying are rated as improving mood (Becht & Vingerhoets, 2002; Vingerhoets, 2013; Vingerhoets et al., 2000; Vingerhoets & Cornelius, 2001). Laboratories also lack a level of privacy as although the participants watch the film alone, they do not watch in privacy; both experimenters and recording equipment will introduce social pressures that are likely to increase attempts to suppress crying (Millings et al., 2016; Simons et al., 2013;

Vingerhoets & Bylsma, 2016). However, one major difference that has not been addressed is the large difference in crying intensity between the crying participants recall in retrospective studies verses the crying witnessed in a laboratory. Participants often recall an episode of intense crying that contains weeping (Becht & Vingerhoets, 2002; Bylsma et al., 2011), whereas in the laboratory, crying is usually mild and rarely contains weeping, and is restricted to watery eyes (Gross et al., 1994).

1.4.2 Interindividual function of crying

Crying seems to be primarily a social signal that is proposed to gather support from observers, usually those in a close relationship with the crier (Vingerhoets et al., 2000). Weeping is central to the communicative function of crying, it is tears that are the major visual component of crying (Reed et al., 2015). The presence of tears make a face look sadder (Hendriks, Croon, et al., 2008; Ito et al., 2019; Provine, 2012; Reed et al., 2015), increase the amount of social support observers indicate they would give (Hendriks, Croon, et al., 2008; Provine et al., 2009[1]), reduce aggression (Riem et al., 2017) and increase attributions of helplessness (van de Ven et al., 2017). The reverse is also found when tears are digitally removed from crying faces. Sadness attributions and levels of social support are reduced (Hendriks & Vingerhoets, 2006; Provine et al., 2009; van de Ven et al., 2017). This is known as the tearing effect (Provine et al., 2009). The tearing effect is robust (Zickfeld et al., 2018), occurs regardless of the facial expression of the crier (Ito et al., 2019; Reed et al., 2015), and happens at a preconscious level (Balsters et al., 2013).

[1]The erased tear paradigm used by Provine (2009) was originally conceptualised, although uncredited, by Randy Cornelius (Baker, 2018; Cornelius et al., 2017)

The signal value of tears can be modulated by top-down cognitive processes. Judgements of whether crying is appropriate can be made when the causes of tears are known (Baker, 2018; Becker et al., 2017; Fischer et al., 2013; Pauw et al., 2019). This is then reflected in competence judgements of the crier, those crying for a non-appropriate reason are rated as less competent than those who cry for a reason considered appropriate (Becker et al., 2017; Fischer et al., 2013). This relationship is linked to the view that crying represents someone's inability to cope (Vingerhoets & Bylsma, 2016). If crying is considered an overreaction to the event, the crier may be judged to be over-emotional and less competent (Becker et al., 2017). The signal value of tears is also modulated by gender. Males who cry are often seen as warm and emotional whereas women are often seen as less competent and overly emotional (van de Ven et al., 2017; Zickfeld et al., 2018). This again is modulated by top down processes, there are some situations where crying is considered a reasonable situation for males to shed tears e.g., during sports (MacArthur & Shields, 2015). There are some contexts where crying is viewed as manipulative and as such lessen the amount of social support offered (Becker et al., 2017). This is of particular focus during conflict with close partners, or in work settings. The differences in gender are explained by an attributional framework where female crying is judged to be crier focused whereas males crying is situational focused (Becker et al., 2017).

Overall, crying seems to be a powerful social signal that's main interindividual function is to elicit social support but also communicates sadness and may work to reduce aggression. There is evidence that crying is modulated by top down processes that modify the way tears are appraised. Despite evidence that top down processes modulate perception of criers, the majority of research is made without context. This seems especially important given that there is always a reason for crying, and that there is a wide variety of situations that can induce crying (Vingerhoets, 2013; Vingerhoets & Cornelius, 2001).

1.4.3 Weeping

Despite all terrestrial mammals having the appropriate physiological apparatus, only humans seem to weep to emotional events. Tears can be a visual signal and when adults weep it is often in the absence of any acoustic components (Gračanin, Bylsma, et al., 2018; Vingerhoets, 2013; Vingerhoets & Cornelius, 2001). Therefore, weeping is not only the most important behaviour in crying, it is often the only perceivable element. It is possible that different crying behaviours serve different functions (Gračanin et al., 2014; Sharman, Dingle, Vingerhoets, et al., 2019). Whilst weeping is the visible signal that has an interindividual function communicating sadness and soliciting support, the reduced breathing rates from sobbing may serve an intraindividual function.

The difficulty in inducing weeping in laboratory has led to some difficulty in studying crying. This is especially prevalent in research which uses physiological dependent variables. The majority of studies have treated different crying behaviours as markers of intensity. For instance, most self-report scales range from ‘felt like crying’ to ‘weeping and wailing’, with ‘watery eyes’ often the dividing line between coding somebody as a crier or not crier (Gračanin et al., 2015; Gross et al., 1994; Sharman, Dingle, Vingerhoets, et al., 2019). In this instance weeping is considered a behaviour of intense crying. However, when studies involve judgements of criers, they exclusively use videos or photos that include tears (Provine et al., 2009). A similar distinction is made by participants themselves, when asked to remember crying episodes, they recall episodes of intense crying that includes weeping (Bylsma et al., 2011). That means the majority of intraindividual studies that induce crying do not meet the same criteria as interindividual studies. Laboratory based studies rarely include weeping, whilst weeping is the minimum criteria for both interindividual and recollection-based studies. This may be one reason evidence for the physiological reduction hypothesis has been mixed, the majority of laboratory based intraindividual studies do not include weeping which may be a necessary part of the arousal reduction mechanism. Furthermore, although studies of tear perception include tears, they are normally digitally added, there is a lack of studies that use dynamic video stimuli that includes *actual* episodes of weeping. Despite the science of adult crying becoming more theory and data driven, compared to speculations made in clinical settings (Vingerhoets & Bylsma, 2016), there is almost no research on episodes of *actual* weeping.

1.5 PhD Outline

This thesis investigates the importance of weeping as a behaviour critical to crying. It investigates this from both the production of weeping and the perception of weeping. Chapter two of this thesis reviews the current methods of passive emotion induction and how physiological reactivity is dictated by the mode of induction as opposed to the emotion induced. This chapter uses heart rate as an index for physiological responding and discusses the most appropriate control baseline for psychophysiological studies. The chapter suggests current nomothetic methods produce only mild emotions. Chapter three explores the psychophysiological response to weeping. The chapter shows how the point of tear production is critical in the physiological response to crying and that after tear production there is a large increase in facial temperatures in the absence of responses in any cardiorespiratory or electrodermal measures. There is a dissociation between facial temperatures and other autonomic systems; this suggests facial temperatures may be functional well as measuring autonomic nervous system activity. Chapter four addresses the psychophysiology of tear suppression. This chapter shows that large physiological responses are attributed to weeping, whereas suppression is characterised by no physiological response. This change is in the absence of any psychological effects suggesting it is the production of the tear that is critical and not the underlying sadness. Chapter five investigates the role of emotional context on weeping. This extends the current interindividual research by using videos of actual weepers and introducing emotional context to highlight top down influences. This chapter shows that judges are accurately detecting sadness in the weepers but also making judgements of increased emotional intensity of the context congruent emotion. This is more pronounced in weepers compared to non-weeping targets. Overall, this thesis shows that weeping is a critical behavioural response with its own psychophysiological profile and has a signal value over and above other crying behaviours.

Chapter 2: Heart rate change during emotion induction: How attention dominates affect.

2.1 Abstract

Some theories of emotion suggest that each emotion is associated with a specific pattern of physiological response. However, recent meta –analyses reveal a lack of consistency in the direction and magnitude of physiological responses associated with different emotions. This is especially prominent with regard to heart rate. We explore the hypothesis that some inconsistencies are due to physiological changes driven by the attentional demands of different emotional induction techniques rather than the emotions themselves. A review was conducted on heart rate change from 284 emotion inductions within 103 studies. We classified the inductions based on emotional categories, dimensions of emotion, and the attentional demands of the induction methodology. The findings suggest that the direction and magnitude of heart rate change was strongly associated with the attentional demands of the induction method regardless of the emotion. One reason for this may be that emotions induced in the laboratory are relatively mild. We suggest that the failure to account for the method of induction can account for some of the physiological inconsistencies in the emotion induction literature.

2.2 Introduction

Changes in autonomic nervous system (ANS) activity have frequently been used as an index emotional reactivity (e.g. Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008; Levenson, 2014; Mauss & Robinson, 2009). Levenson (2014) suggests “When it comes to emotion, all roads lead to the autonomic nervous system” (p. 100). However, scientists disagree on the extent to which emotional categories have specific physiological ‘fingerprints’ (Kreibig, 2010; Lench et al., 2011; Levenson, 2003; Lindquist et al., 2013; Siegel et al., 2018; Stemmler, 2004). Heart rate (HR) is the most commonly used ANS measure, but there is very little consistency in the direction or magnitude of HR reactivity across different studies for the same emotion (Kreibig, 2010). This paper presents a review of published HR responses, showing that in laboratory situations *how* we induce emotions accounts for more of variance in HR responses than *what* emotion we induce.

The relationship between physiology and emotions reflects the wider debate on the nature of emotions. Basic Emotion Theory views emotions as categories with ‘fuzzy’ boundaries (Cowen & Keltner, 2017). This ‘categorical’ theory suggest that there exists emotional categories with strong biological components (Lindquist et al., 2013). The major alternative hypothesis is the constructionist view of emotions. Constructionist theories suggest emotions are a language and culture driven categorisation system which lacks strong biological ties (Barrett, 2006; Russell & Barrett, 1999). They suggest physiological responses to emotions are a product of underlying dimensions such as attention, arousal or approach/avoid tendencies (Barrett, 2014). Therefore, according to this dimensional theory, ANS activity would more greatly discriminate between emotions far apart in dimensional space, whereas emotions of similar dimensional properties, would share more common physiological responses. Hence, distinguishing between theories relies heavily on an accurate assessment of the physiological correlates of each emotion. For example, emotions that are high in arousal are accompanied by increases in HR (Bradley, 2000; Kreibig, 2010; Van Witvliet & Vrana, 1995). Interestingly, the dimension which appears most frequently, emotional valence, appears to have very little influence on physiological responses (Kreibig, 2010; Lench et al., 2011; Siegel et al., 2018).

To date, there have been four major meta-analyses (Larsen et al., 2008; Lench et al., 2011; Siegel et al., 2018; Stemmler, 2004) and a comprehensive review (Kreibig, 2010) examining the ‘fingerprint’ hypothesis of emotions. The results of the meta-analyses show some support for the physiological specificity; however, they are far from conclusive. Three reviews (Larsen et al., 2008; Lench et al., 2011; Stemmler, 2004) revealed evidence that anger and fear could be distinguished by cardiovascular activity. Anger was related to higher diastolic blood pressure, larger increases in peripheral resistance, but smaller increases in stroke volume and cardiac output (Larsen et al., 2008). Lench et al., (2011) further claimed that it was possible to distinguish between happiness, fear, anxiety and sadness using ANS activity in combination with further cognitive and behavioural measures. However, all four meta-analyses were unable to identify clear physiological boundaries between emotional categories. Kreibig's (2010) review ignored the magnitude of physiological responses and instead focused on the direction of ANS responses e.g., whether HR increased or decreased. Kreibig's (2010) review reveals discrepancies in the direction of ANS changes between different studies of the same emotion. These discrepancies were most prominent for HR and HR variability. For example, Kreibig, (2010) found that ten out of the fifteen emotions examined (sadness, fear, anxiety, anger, disgust, amusement, happiness, pleasure, pride and joy) have been associated with both an increase and a decrease in HR. Despite this inconsistency in reported

HR reactivity, it is still the most commonly reported ANS measure (Kreibig, 2010; Siegel et al., 2018). Furthermore, HR provides us with an overall marker for ANS activity (Berntson et al., 1997) and it therefore seems important to investigate why there are inconsistencies in HR associated with the emotions.

This inconsistency in HR responses to emotion inductions calls into question both the categorical theory (Quigley & Barrett, 2014) and the dimensional theory of emotions. If emotions are categorically discrete, with discrete causal mechanisms, we should expect a high level of consistency in the associated HR changes. Likewise, if the dimensional theory is correct, we would still expect similarities across emotions sharing underlying dimensions. Although there is often disagreements on the precise orientation of the dimensions (Russell & Barrett, 1999) the presence of a valence dimension, running from positive to negative or pleasant to unpleasant, is present in many, if not all, dimensional theories. For example, happiness is suggested as the polar opposite of sadness. The second most common dimension involves arousal, with emotions ranging from arousing to non-arousing (Fontaine et al., 2013; Russell & Barrett, 1999). For example, in terms of arousal, fear is the polar opposite of sadness. There are some subtle differences in the conceptualisation of the arousal dimension which leads to differences on where emotional categories are positioned on an arousal dimension. For example, Russell and Barrett (1999) place disgust as slightly activating, whilst, Fontaine et al., (2013) suggest disgust is low arousal. Therefore, we will examine both arousal dimensions. The final dimension we address is potency or dominance (Bradley & Lang, 1994). This has often been incorporated into the arousal dimension but distinguishes emotions based on whether the experience of the emotion involves control over the situation. For example, in terms of potency, anger is the polar opposite of sadness (Fontaine et al., 2013). If the physiological response is tied to an underlying dimension of emotion, we would expect one or more of these dimensions to account for a significant proportion of the variance found in HR responses to emotion.

We suggest that the lack of consistency across studies may be significantly influenced by aspects of the experimental design that are not related to the specific emotion. HR as part of the ANS plays a critical role in the basic mechanisms of physiological homeostasis (Elliott, 1972). The ANS also plays a role in routine, non-affective attentional processes (Porges, 1992). For example, attentional demands and cognitive effort has been shown to have strong physiological correlates (Cacioppo & Sandman, 1978). The 'intake-rejection' hypothesis (Lacey, Kagan, Lacey, & Moss, 1963) suggests that cardiac deceleration is associated with tasks involving the 'intake' of environmental stimuli (e.g. watching a video), whereas cardiac acceleration is associated with tasks involving reflection and the 'rejection' of environmental stimuli (e.g. mental calculations). For example, Kaplan, Corby, and Leiderman, (1971) found that looking at numbers on a screen decreased HR, but adding the numbers or speaking them out loud, increased HR. Furthermore, there appears to be a monotonic relationship between task difficulty and HR change. For example, visual search tasks with low discriminability, which are therefore more difficult, resulted in greater HR deceleration than high discriminability tasks (Coles, 1972). However, Lacey et al., (1963) acknowledged that most tasks are rarely pure 'intake' or 'rejection' and often have elements of both. The 'intake-rejection' hypothesis has been extensively investigated and significant findings with large effect sizes are consistently reported (Carroll & Anastasiades, 1978). Unlike many findings in psychology (Open Science Collaboration, 2015), there is consistent evidence that the intake-rejection effect is easy to replicate. Although there are differences in the magnitude of the changes, all participants do change in the same direction. Given the robust nature of the effects of attentional demands on direction of HR change, it would be reasonable to hypothesise that the attentional component of different types of emotion induction would have an influence on HR (McGinley & Friedman, 2017). Some induction studies involve a strong intake component (e.g. watching videos) whereas others have a strong rejection component (e.g. reflecting on past experiences). Therefore, HR change could be a function of the emotion induced *and* the method of induction. However, the majority of the studies on the psychophysiology of emotion demonstrate a relative neglect of the role of psychological factors other than emotion on HR, including the attentional demands of the induction method.

We explore the hypothesis that some of the inconsistency of results found in the literature can be explained by the failure to take into account the effect of attentional demands of different types of emotion induction. The effect of particular emotions on HR response may be affected by the attentional effects of particular induction techniques. Emotion induction techniques can be broadly separated into two types. The first type are passive situations, which are described as non-metabolically demanding techniques which involve a strong attentional component. Passive situations are the most common type of emotion induction used in psychological research (Kreibig, 2010). Thus this research focuses on these non-metabolically demanding emotion induction techniques. These include watching films, looking at pictures, imagery scripts or recalling from memory. The second type of inductions are called 'motivated performance situations' (Kassam & Mendes, 2013) and involve more immersive techniques, such as giving a speech or maths tests, where emotions are generated 'in vivo' with the participant as an actor in the situation. Whilst motivated performance situations are likely to generate stronger emotions there are a number of limitations. The induction of certain emotions may involve ethical problems, e.g. fear, or be impossible to create in the laboratory, e.g.

love. Given that passive situations are the most commonly used method in the literature, and contain a strong attentional component, it is important to understand how much variance in HR is accounted for by the attention component.

We review HR changes from a resting baseline across published studies which include HR as a dependent variable and compare emotional inductions that use either an intake or rejection induction technique (Lacey et al., 1963). Furthermore, we will compare this to other factors which may be accounting for the variance in heart rate. We will compare discrete emotional categories and emotions at opposite ends of three emotional dimensions: valence (Russell, 1980), arousal (Fontaine et al., 2013; Russell, 1980) and potency (Fontaine et al., 2013). It is hypothesised that the intake-rejection hypothesis will provide the best explanation for the reported HR change in passive emotion induction studies. Furthermore, we will explore how the use of a 'vanilla' baseline may control for the attentional demands of the emotional stimulus.

2.3 Method

2.3.1 Selection of studies

Database searches were conducted for relevant studies that included the keywords 'emotion' with 'heart rate' in PubMed (N = 986) and Psychinfo (N = 1640). We removed duplicates and used the following criteria to compile the final list of articles: The article was published in a peer reviewed journal, was an original empirical study (not meta-analysis or review), it was written in English, it used non-clinical adult participants, it contained a passive emotion induction task, HR or HR reactivity was reported as a dependant measure, and a resting baseline and/or neutral stimulus condition was reported. In total 103 studies met the criteria. Many of the studies induced more than one emotion giving a total of 284 discrete emotion inductions (Table 2.1).

Table 2.1. Overview of studies that measured HR reactivity in passive emotion inductions

No.	Study	Inductions	Emotions	Method	Induction type	Baseline
1	Abercrombie et al., 2008	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
2	Allen et al., 1996	2	Unpleasant	Imagery Script	Rejection	Resting
3	Alpers et al., 2011	4	Pleasant, unpleasant, anger, happy	Pictures	Intake	Resting, neutral
4	Aue et al., 2007	2	Fear	Pictures	Intake	Resting, neutral
5	Averill, 1969	2	Sadness, Humour	Film	Intake	Resting, neutral
6	Baldaro et al., 1996	2	Pleasant, unpleasant	Film	Intake	Resting
7	Baldaro et al., 2001	1	Unpleasant	Film	Intake	Resting, neutral
8	Bernat et al., 2006	4	Pleasant, unpleasant, happy, fear	Pictures	Intake	Resting, neutral
9	Bos et al., 2013	3	Fear, Pleasant	Film	Intake	Resting, neutral
10	Bradley et al., 2001	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
11	Bradley et al., 1993	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
12	Bradley et al., 2008	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
13	Britton et al., 2006	3	Pleasant, happy, sad	Film	Intake	Resting, neutral
		1	Disgust	Pictures	Intake	Resting, neutral
14	Cacioppo & Sandman, 1978	1	Disgust	Pictures	Intake	Resting
15	Carvalho et al., 2012	4	Pleasant, unpleasant, fear	Film	Intake	Resting, neutral
16	Chloe et al., 2013	4	Unpleasant, sad, fear	Film	Intake	neutral
17	Christie & Friedman, 2004	6	Humour, anger, content, disgust, fear, sad	Film	Intake	Resting, neutral
18	Codispoti & De Cesarei, 2007	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
19	Codispoti et al., 2008	2	Pleasant, unpleasant	Film	Intake	Resting, neutral

20	Courtney et al., 2010	1	Fear	Pictures	Intake	neutral
21	Critchley et al., 2005	4	Happy, sad, anger, disgust	Pictures	Intake	Resting
22	Davidson & Schwartz, 1976	1	Anger	Memory	Rejection	Resting, neutral
23	Davydov et al., 2011	2	Sad	Film	Intake	Resting
24	De Jong et al., 2011	1	Disgust	Film	Intake	neutral
25	Demaree et al., 2004	2	Disgust, humour	Film	Intake	Resting
26	Dimberg, 1986	1	Fear	Pictures	Intake	Resting
27	Dimberg & Thunberg, 2007	1	Happy, anger	Pictures	Intake	Resting
28	Ekman et al., 1983	6	Anger, fear, sad, happy, surprise, disgust	Posed facial expression & memory	Rejection	Resting
29	Elices et al., 2012	3	Anger, fear, sad	Film	Intake	Resting
30	Erisman & Roemer, 2011	2	Humour, fear	Film	Intake	Resting
31	Etzel et al., 2006	3	Happy, fear, sadness	Music	Intake	Resting
32	Fernández et al., 2012	6	Anger, fear, sad, disgust, pleasant, humour	Film	Intake	Resting, neutral
33	Fiorito & Simons, 1994	5	Fear, anger, sad, happy	Imagery Script	Rejection	Resting
		2	Pleasant, unpleasant	Memory	Rejection	Resting
34	Flykt, 2005	1	Fear	Pictures	Intake	Resting, neutral
35	Foster & Webster, 2001	2	Anger, humour	Memory	Rejection	Resting
36	Foster et al., 1998	1	Anger	Imagery Script	Rejection	Resting
		1	Anger	Memory	Rejection	Resting
37	Foster et al. , 2003	1	Humour	Imagery Script	Rejection	Resting
		1	Humour	Memory	Rejection	Resting
38	Fredrickson & Levenson, 1998	2	Fear, sad	Film	Intake	Resting
39	Golland et al., 2014	2	Pleasant, unpleasant	Film	Intake	Neutral
40	Gross, 1998	1	Disgust	Film	Intake	Resting
41	Gross & Levenson, 1993	1	Disgust	Film	Intake	Resting
42	Gross & Levenson, 1997	2	Sad, humour	Film	Intake	Resting, neutral
43	Gross et al., 1994	1	Sad	Film	Intake	Resting
44	Grossberg & Wilson, 1968	1	Fear	Imagery Script	Rejection	Resting, neutral
45	Gruber et al., 2009	1	Happy	Memory	Rejection	Resting

46	Hamer et al., 2007	2	Anger, sad	Memory	Rejection	Resting
47	Harrison et al., 2000	2	Humour, happy	Film	Intake	Resting, neutral
48	Hendriks et al., 2007	1	Sad	Film	Intake	neutral
49	Herbert et al., 2010	2	Pleasant, unpleasant	Pictures	Intake	Resting
50	Herring et al., 2011	2	Humour, happy	Film	Intake	Resting
51	Hess et al., 1992	4	Content, sad, happy, anger	Imagery Script	Rejection	Resting
52	Hubert & de Jong-Meyer, 1990	2	Pleasant, unpleasant	Film	Intake	Resting
53	Jönsson & Sonnby-Borgström, 2003	2	Anger, happy	Pictures	Intake	Resting
54	Khalfa et al., 2008	2	Happy, sad	Music	Intake	Resting
55	Kleim et al., 2010	1	Unpleasant	Imagery Script		Resting
56	Klorman et al., 1977	1	Disgust	Pictures	Intake	Resting, neutral
57	Kornreich et al., 1998	4	Happy, anger, sad, disgust	Film	Intake	Resting
58	Kreibig et al., 2007	2	Fear, sad	Film	Intake	Resting, neutral
59	Kreibig et al., 2013	3	Humour, Disgust	Film	Intake	Resting
60	Kreibig et al., 2015	3	Humour, Disgust	Film	Intake	Resting
61	Krumhansl, 1997	4	Sad, fear, happy	Music	Intake	Resting
62	Kunzmann & Grühn, 2005	1	Sad	Film	Intake	Basal
63	Labouvie-Vief et al., 2003	4	Anger, fear, sad, happy	Imagery Script	Rejection	Resting
64	Lackner et al., 2013	1	Pleasant	Film	Intake	Neutral
65	LeBlanc et al., 2016	3	Sad, fear, humour	Film	Intake	Resting, neutral
66	Levenson et al., 1991	4	Anger, fear, sad, disgust	Directed facial expression	Rejection	Neutral
		4	Anger, fear, sad, disgust	Memory	Rejection	Resting
67	Levenson et al., 1990	5	Anger, fear, sad, disgust, happy	Directed facial expression	Rejection	Neutral
68	Levenson et al., 1992	5	Anger, fear, sad, disgust, happy	Directed facial expression	Rejection	Neutral
69	Lobbestael et al., 2008	1	Anger	Film	Intake	Neutral
70	Marci et al., 2007	3	Anger, happy, sad	Imagery Script		Resting

71	Miller et al., 1987	5	Fear, anger, pleasant, unpleasant	Imagery Script	Rejection	Resting, neutral
72	Montoya et al., 2005	2	Anger, fear	Film	Intake	Neutral
73	Neumann & Waldstein, 2001	4	Sad, anger, content, happy	Memory	Rejection	Resting
74	Nyklíček et al., 1997	4	Happy, content, sad, unpleasant	Music	Intake	Resting, neutral
75	Overbeek et al., 2012	7	Anger, disgust, sad, fear, surprise, happy	Film	Intake	Resting, neutral
		7	Anger, disgust, sad, fear, surprise, happy	Pictures	Intake	Resting, neutral
76	Palomba et al., 2000	2	Fear, disgust	Film	Intake	Resting, neutral
77	Pastor et al., 2008	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
78	Peira et al., 2012	1	Fear	Pictures	Intake	Resting, neutral
79	Prkachin et al., 1999	5	Happy, anger, fear, sad, disgust	Imagery Script	Rejection	Neutral
80	Rainville et al., 2006	4	Anger, fear, happy, sad	Memory	Rejection	Resting
81	Rash & Prkachin, 2013	1	Sad	Memory	Rejection	Resting
82	Ritz et al., 2000	2	Happy, sad	Pictures	Intake	Resting, neutral
		2	Happy, sad	Imagery Script	Rejection	Resting, neutral
83	Roberts & Weerts, 1982	2	Fear, anger	Imagery Script	Rejection	Resting, neutral
84	Rottenberg et al., 2002	1	Sad	Film	Intake	Neutral
85	Rottenberg et al., 2003	1	Sad	Film	Intake	Neutral
86	Sánchez-Navarro et al., 2008	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
87	Schumacher et al., 2015	2	Pleasant, unpleasant	Pictures	Intake	Resting, neutral
88	Schwartz et al., 1981	5	Happy, sad, anger, fear, content	Memory	Rejection	Resting, neutral
89	Sebastiani et al., 2014	1	Fear	Pictures	Intake	Resting, neutral

90	Shenhav & Mendes, 2014	2	Disgust	Film	Intake	Resting, neutral
91	Shiota et al., 2011	5	Pleasant, humour, surprise	Pictures	Intake	Resting, neutral
92	Sinha et al., 1992	5	Happy, sad, fear, anger	Imagery Scripts	Rejection	Resting, neutral
93	Sokhadze, 2007	1	Disgust	Pictures	Intake	Resting, neutral
94	Stephens et al., 2010	6	Humour, anger, content, fear, sad, surprise	Film/Music	Intake	Resting, neutral
95	Tsai et al., 2000	2	Sad, humour	Film	Intake	Neutral
96	Valderas et al., 2015	2	Happy, fear	Film	Intake	Neutral
97	Van Witvliet & Vrana, 1995	4	Fear, sad, happy, pleasant	Imagery Scripts	Rejection	Resting
98	Vrana, 1993	4	Disgust, anger, pleasant, happy	Imagery Scripts	Rejection	Resting
99	Vrana & Gross, 2004	2	Anger, happy	Pictures	Intake	Resting, neutral
100	Vrana & Rollock, 2002	3	Happy, anger, fear	Imagery Scripts		Resting, neutral
101	Waldstein et al., 2000	2	Happy, anger	Film	Intake	Resting
		2	Happy, anger	Memory	Rejection	Resting
		2	Happy, anger	Imagery Script	Rejection	Resting
102	White & Rickard, 2015	2	Happy, sad	Music	Intake	Resting
103	Yaroslavsky et al., 2013	1	Sad	Film	Intake	Resting

2.3.2 Coding of studies

Two coders categorised the inductions on five dimensions: Lacey's intake-rejection hypothesis, Russell & Barrett's valence dimension, Russell & Barrett's arousal dimension, Fontaine et al. arousal dimension, and Fontaine et al. potency dimension. There was high agreement between the coders (Cohen's $K = .89$, $SE = .06$, $p < .001$). Any disagreements were resolved by discussion.

Lacey's intake rejection hypothesis

The studies featured many different types of passive induction method and we classified them as either an intake task, when the stimulus involved paying attention to an external source e.g., watching a film, or a rejection task, when the stimulus involved introspective processes and thus 'rejecting' external cues e.g. remembering from memory. Intake tasks were used more frequently than rejection tasks: intake tasks [n = 180] (film clips [n = 99], pictures [n = 61], music [n = 14], a combination of film clips and music [n = 6]); rejection tasks [n = 104] (recalling from memory [n = 30], mental imagery [n = 54], posed facial expressions [n = 14] and combination of posed facial expressions and mental imagery [n = 6]).

Emotional categories

We coded the emotion induced according to how it was defined by the original authors. We then grouped them together to form eight emotional categories (Kreibig, 2010). This included the emotional categories of: sadness [n = 48], happiness [n = 42], fear [n = 45], anger [n = 40], disgust [n = 26], humour [n = 19], contentment [n = 7], and surprise [n = 5]. If there was no obvious emotional category, we coded the induction by valence as unpleasant [n = 24] or pleasant [n = 29].

Russell & Barrett (1999) valence dimension (displeasure to pleasure)

The valence dimension was used to classify emotional categories into either positive or negative emotions. There were overall 183 negative inductions in five negative emotions categories: sadness [n = 48], fear [n = 45], anger [n = 40], disgust [n = 26], and unpleasant [n = 24]. There were four positive emotion categories with

97 discrete inductions happy [*n* = 42], pleasant [*n* = 29], humour [*n* = 19], contentment [*n* = 7].

Russell & Barrett (1999) arousal dimension (activation to deactivation)

The first arousal dimension was used to classify emotional categories into either activating or deactivating arousal. There were 179 inductions classified as activation. This included the emotional categories of fear [*n* = 45], anger [*n* = 40], happy [*n* = 41], disgust [*n* = 26], humour [*n* = 17], surprise [*n* = 5], unpleasant [*n* = 3], and pleasant [*n* = 3]. There were 54 inductions associated with deactivation. This included the emotional categories of sadness [*n* = 48], contentment [*n* = 6], and humour [*n* = 1].

Fontaine, Scherer & Soriano (2013) arousal dimension (high to low)

The second arousal dimension was used to classify emotional categories into either high or low arousal. There were 156 inductions classified as high arousal. This included the emotional categories of fear [*n* = 45], happy [*n* = 42], anger [*n* = 40], humour [*n* = 19], surprise [*n* = 5], pleasant [*n* = 4], and unpleasant [*n* = 1]. There were 81 inductions associated with low arousal. This included the emotional categories of sadness [*n* = 48], disgust [*n* = 26], contentment [*n* = 6], and pleasant [*n* = 1].

Fontaine, Scherer & Soriano (2013) potency dimension (high to low)

The potency dimension was used to classify emotional categories into either high or low potency. There was 189 inductions classified as high potency. This included the emotional categories of sadness [*n* = 48], happy [*n* = 42], anger [*n* = 40], humour [*n* = 19], contentment [*n* = 6], surprise [*n* = 5], and pleasant [*n* = 3].

There were 48 inductions classified as low potency. This included the emotional categories of fear [*n* = 45], unpleasant [*n* = 1], and pleasant [*n* = 2].

2.3.3 Coding of heart rate

We analysed the difference in HR between an emotion induction and a control condition for each of the 284 induction procedures. The reporting of HR varied between studies and classifying direction of change relied on the presence of a baseline measurement. We calculated differences in HR (HR change) between emotional induction and baseline (mean HR in baseline condition – mean HR in the emotion induction) from both a resting baseline measurement (246 inductions from 87 studies) and from a comparable neutral stimulus (163 inductions from 59 studies). We considered a neutral stimulus as comparable if it was the same mode of presentation (e.g. neutral video vs. emotion video) as the method used for inducing the target emotion. Some studies included both a resting and neutral stimulus baseline measurements (*n* = 42 studies, 126 inductions), therefore, these studies received two different HR change scores. HR was usually measured in beats per minute (bpm) or inter-beat interval (IBI). We converted any measures of IBI to bpm (HR = 60000 / IBI [milliseconds]). Some inductions used normalised scoring (*Z*, *n* = 16) so magnitude of difference could not be used; therefore these were only coded for an increase or decrease in HR. An increase in HR would mean higher average HR in the emotion induction versus the baseline whereas a decrease in HR would mean a lower average HR in the emotion induction versus the baseline.

2.4 Results

2.4.1 Direction of heart rate change

To analyse which of the potential explanations for heart rate best accounts for the pattern of heart rate change found in passive emotion inductions, a series of Chi-square tests were conducted on direction of heart rate change and each of the explanations. Table 2.2 shows the intake-rejection hypothesis and categorical view accounted for a significant amount of the variation in direction of HR change.

Table 2.2. Chi square summary statistics for each of the possible explanations of heart rate

	n	χ^2 (df)	*p*	Cramer's V
Lacey's Intake Rejection	**246**	**124.57 (1)**	**<.001**	**.71**
Emotional Categories	168	12.55 (4)	.014	.27
Fontaine Arousal	203	2.22 (1)	.14	.11
Fontaine Potency	203	1.92 (1)	.17	.10
Russell Valence	233	1.29 (1)	.26	.07
Russell Arousal	199	.02 (1)	.89	.01

Note: Bold indicates significance after alpha level adjusted using a Bonferroni correction for multiple comparisons ($\alpha = .008$).

There was a significant relationship between direction of HR change from baseline and whether the induction method was intake or rejection. HR decreases were associated with intake tasks, whereas HR increases were more likely to be associated with rejection tasks with a very large effect size (see Figure 2.1).

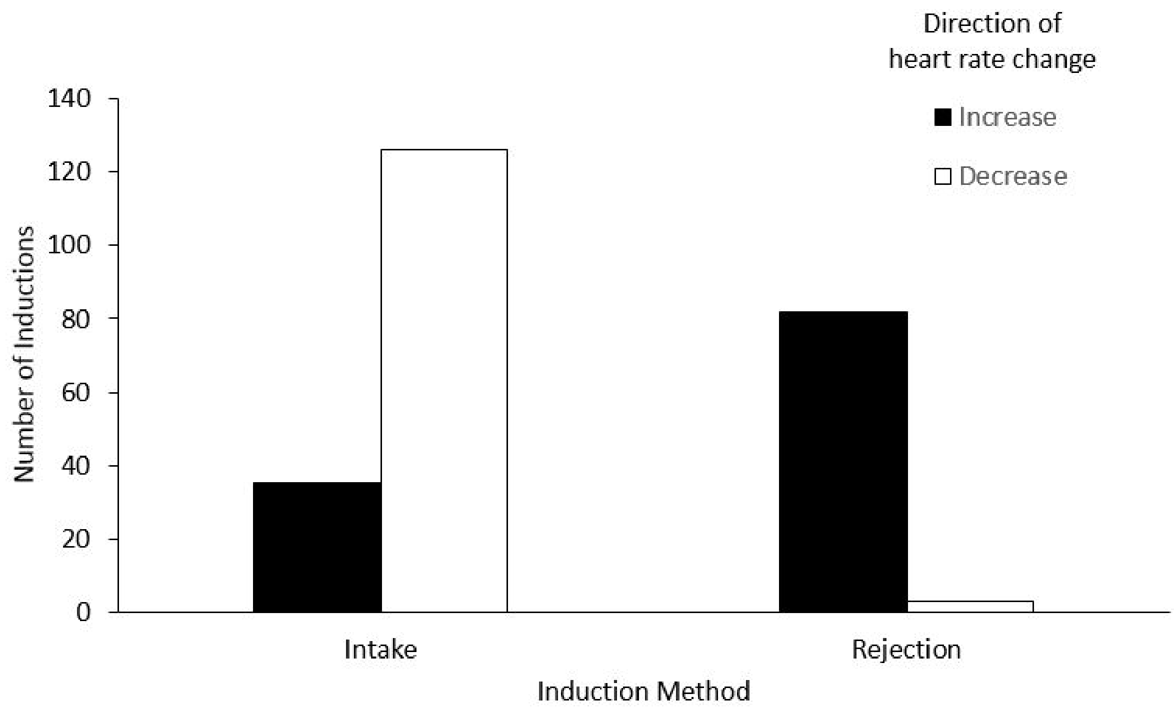

Figure 2.1. Direction of HR change from a resting baseline as a function of induction methodology (intake or rejection).

To check for pseudoreplication errors (Waller, Warmelink, et al., 2013) that may explain the effect of intake-rejection, an additional analysis was conducted using only one induction from each of the 87 studies that reported HR change from a resting baseline. The first induction reported in the paper was used if more than one emotion was induced. The pattern remained the same (χ^2 (1) = 37.86, p < .001, V = .67) with a small reduction in effect size. This suggests that pseudoreplication is not vitiating the results of the original analysis.

2.4.2 Magnitude of heart rate change from a resting baseline.

The magnitude of HR change was explored with a set of one-way ANOVA's. The independent variables were the six different hypothesised factors which may explain HR change. The dependent variable was the difference in HR between a resting baseline and emotional induction. Table 2.3 shows only Lacey's intake-rejection hypothesis accounted for a significant portion of the variance. Heart rate change from a resting baseline was significantly higher for rejection tasks (*M* = 5bpm, CI95% [4.10: 5.90]) than for intake tasks, which had an overall decrease from baseline (*M* = -0.75bpm, CI95% [-1.34: -0.16) with a large effect.

Table 2.3. ANOVA summary statistics on heart rate change from a resting baseline grouped by different hypothesised underlying dimensions of emotion.

	F(df)	p	η_p^2
Lacey's Intake Rejection	**117.95(1, 228)**	**<.001**	**.34**
Russell Valence	3.80 (1, 216)	.052	.02
Categorical (Basic)	2.37 (3, 128)	.074	.05
Fontaine Potency	2.89 (1, 185)	.091	.02
Fontaine Arousal	2.81 (1, 185)	.096	.01
Russell Arousal	.11 (1, 181)	.746	.001

Note: Bold indicates significant after alpha level adjusted using a Bonferroni correction for multiple comparisons (α = .008).

2.4.3 Differences in HR between emotion inductions and a neutral control stimulus.

The intake-rejection hypothesis suggests that the attentional demands of the stimulus modulate HR. If HR change in emotional inductions is a product of the attentional demands, the next step is to compare heart rate responses in neutral conditions with matched attentional demand, for example, using non-emotional videos as a control for emotional videos. If the attentional demands are the main causal mechanism for HR change, we should see no difference between emotional and non-emotional videos because they both require similar attentional demands.

To explore whether using a neutral stimulus reduces effects associated with the induction method, we tested for a relationship between induction task type and a comparable neutral stimulus (*n* = 166). The difference in HR was calculated (HR in emotion induction – HR from a comparable neutral stimulus). An independent group t-test was used to calculate whether there is any difference between inductions using an intake or rejection task. Emotions induced using rejection methods had a significantly larger HR change (*n* = 43, *M* = 4.40, *SE* = 0.48) than emotions induced using an intake task with a very large effect size (*n* = 120, *M* = .21, *SD* = .15, *p* <.001, *d* = 1.69). The group means show that there was little HR difference between emotional and non-emotional intake tasks, whilst there was a difference between emotional and non-emotional rejection tasks.

2.5 Discussion

We reviewed HR change across multiple studies and emotion inductions comparing categories of emotion, underlying dimensions, and attentional demands of the stimulus as possible explanations for HR change. For both direction and magnitude we found strong support for the hypothesis that HR in passive emotion inductions is strongly influenced by the attentional levels of the induction method supporting predictions made by the intake-rejection hypothesis (Lacey et al., 1963). There were very large effect sizes which suggests that mode of induction was a major factor in determining the direction of HR change and the magnitude of HR change; the emotion being induced appears to be a much less important determinant of HR change in these contexts. The results of our analyses may help to explain some of the lack of consistency found in the HR changes found in passive emotion induction studies (e.g. Kreibig, 2010).. HR for intake tasks was consistently lower than resting baseline measurements, indicating a decrease in HR, whilst the opposite pattern was found for rejection tasks.. The data suggests that HR in emotional inductions can be attributed to *how* we induce emotions and not *what* emotion is being induced.

Although we found no effect of arousal, potency, valence or emotion category on either the direction or magnitude of HR changes, this may not be true of other measures of psychophysiology. For instance, the arousal dimension of the emotion maybe strongly influenced by SNS activity which doesn't have a large effect on HR (Berntson et al., 1997) but is critical in skin conductance responses. One reason why the attentional demand has a strong effect on the direction of HR change may be that in most laboratory studies the emotion induced is relatively mild. For instance, Wilhelm and Grossman (2010) found electro-dermal responses whilst watching sport at home were five times higher than laboratory induced stress tasks. Whilst laboratory induced emotions may not be that strong, we know that attentional demands do have robust effects on HR in the laboratory (Carroll & Anastasiades, 1978). Therefore the very robust attentional influences of the mode of induction may have a strong effect *relative* to the mild emotion induced in the laboratory. Laboratory induced emotions may be just too mild to elicit a cardiac response. In non-laboratory situations, where emotion is much more intense, the effect of the emotion on HR may dominate any attentional effects. The contradictory evidence regarding HR change observed in laboratory studies of emotion may simply be an artefact of the mildness of the emotions induced.

The use of a vanilla baseline (a non-emotional variant of the emotion induction stimulus) controls for the attentional demand of the induction stimulus (Jennings et al., 1992). The use of a vanilla baseline removed the effect of the induction method by introducing the same type of attentional demands in the baseline as there is in the emotional stimulus. For intake tasks, the reported HR in emotional inductions was very similar to HR in non-emotional controls. The overall mean difference was just 0.25bpm. However, this was not the case for rejection tasks where there was still a 4.5bpm difference between the emotion inductions and the non-emotional control conditions. There are two clear points as a result of this evidence, emotions seem to be having little effect on HR passive emotion inductions using an intake method, and second, we can control for the attentional demands of the intake task by using a vanilla baseline.

For rejection tasks, HR was higher in the emotion condition than the neutral condition. It may be that rejection methods are more personally relevant and therefore more intense. They are often based on recalling emotional events that were actually experienced outside of the laboratory. In this sense, the participant was directly impacted by the emotion eliciting event. Whereas for intake tasks, such as watching a film, participants may be experiencing the emotions through empathic or vicarious mechanisms (Paulus et al., 2013). This personal relevance may be leading to the induction of more intense emotions which is reflected in the increased HR. Future research will be needed to empirically address the impact of emotional intensity and whether personal relevance of stimuli is driving increased HR reactivity . An alternative explanation for why we see increased HR responses in the emotional induction compared to a vanilla baseline for rejection tasks is that there may be a difference in task difficulty. Magnitude of HR reactivity has been shown to increase with task difficulty (Coles, 1972) and it may be that imagining or remembering an emotional situation is substantially more difficult than a neutral version of the task. This is then reflected in higher HR in the emotional induction due to task difficulty. Future research should explore the contribution of emotional induction task difficulty to HR change.

Throughout this review, we have found strong support for the hypothesis that the mode of emotional induction affects HR. Whilst understanding of the role of the induction method on physiological reactivity is not new (McGinley & Friedman, 2017), we provide a way to understand this effect based on the intake-rejection hypothesis. There are a few important caveats. It will be important that we explore the effect of the intake-rejection hypothesis on more modern measures of cardiac activity such as HR variability. HR variability allows us to look beyond the total ANS influence on the heart by looking at measures specific to both the sympathetic and parasympathetic branches of the ANS (Berntson et al., 1997; Silva et al., 2017). Furthermore, we have addressed inconsistencies in HR only. No theories of emotion suggest that emotions can be separated by HR alone. However, HR does give us an excellent measure for overall ANS activity and was the focus of the original research on intake-rejection. The intake-rejection research is dated and research into the intake rejection hypothesis has declined over the past thirty years[2]. The intake-rejection hypothesis has seen a resurgence of interest in the cognitive psychology literature, now referred to as 'internal or external directed attention' (Chun et al., 2011), although measurements during this resurgence are focused on neurocircuitry and not the ANS. Despite the intake-rejection hypothesis not crossing the divide between the cognitive and affective literatures, Lacey's hypothesis explains the direction and magnitude of HR change in passive emotion inductions with a large effect. For this reason, we believe it warrants further attention in the psychophysiology of emotion.

We suggest that future studies that induce emotions should employ controls to isolate the physiological changes due to both affective and attentional components of stimuli. We recommend a *within*-participant experimental design with use of a vanilla baseline (Jennings et al., 1992). It is important that the vanilla baseline matches the mode of the emotion induction procedure. For instance, a non-emotional film as a control for an emotion inducing film. Given the differences in HR data

[2] Source (ttps://books.google.com/ngrams/graph?content=intake-rejection&year_start=1950&year_end=2008).

between intake and rejection tasks it may only be appropriate to compare physiological responses to different emotions if they use the same induction methodology. Emotions generated by film may not be comparable with emotions generated by memory recall.

In summary, we have presented strong evidence that some of the inconsistency in the emotion induction literature regarding the relationship between HR and specific emotions, can be explained by a failure to control for the mode of induction. Furthermore, mode of induction seems to have a major effect on the direction and magnitude of HR regardless of the emotion. We suggest that the failure to account for the mode of induction has made testing for emotional 'fingerprints' difficult. The principle that physiological responses are the result of multiple psychological processes was not lost on Lacey (J. I. Lacey & Lacey, 1974). He suggests that "it is the nature of the total *transaction* of the subject with his environment, rather than isolated stimulus attributes, which will determine physiological response" (p. 547). This review has not only highlighted a way to explain HR inconsistencies in the emotion literature but has provided a framework for them to be understood. The differences between intake and rejection tasks are as robust in the emotion literature as it is in the cognitive literature.

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Data

The data used for this manuscript has been made available on the OSF repository

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Chapter 3: The psychophysiology of weeping

3.1 Abstract

Emotional crying is often reported to be good for health, however, the empirical evidence has been mixed. A paradox of crying exists; at the time of crying there is an increase in negative affect but when people are asked to recall crying episodes, they often report crying improved their mood. One major difference between laboratory induced crying and naturalistic crying is in intensity. It may be the case that feelings of mood improvement are associated with the tear production process in episodes of intense crying. It is often the case that laboratory induced crying does not include the actual shedding of tears and tends to be restricted to watery eyes. This study aims to induce and measure intense crying that includes weeping. .To increase the rate of weeping we employed an idiographic induction technique that is rarely used in psychological research but has been found to increase the intensity of induced emotions. Forty females choose their own stimulus film that had previously made them weep. Twenty of the participants wept and were compared to twenty participants who did not weep. Episodes of weeping were associated with extremely large temperature increases in the face. This was despite the absence of a large response in heart rate, skin conductance and respiration. Compared to the non-weeping group, weepers rated themselves as sadder, more aroused and had larger facial temperature increases after their tears. The thermal response also correlated strongly with the participants' subjective ratings of emotion. The data are consistent with the majority of the scientific literature on crying but does show how there is a

difference between crying with tears and crying without tears. Therefore, studies which do not distinguish between crying with and without tears are missing a critical element of participants experiences of crying. This study also highlights the importance of thermal imaging as a measurement technique which may of interest to research on emotions with strong autonomic communicative behaviours such as weeping.

3.2 Introduction

Emotional crying (hereby referred to as crying) is a unique and universal human behaviour (Vingerhoets & Cornelius, 2001) which at its most intense involves weeping; the shedding of tears from the eyes (Gračanin et al., 2014). Whilst weeping is considered the most important characteristic of crying (Vingerhoets et al., 2000), there are other behaviours associated with less intense crying episodes including watery eyes, ‘choking-up’, and sobbing; the convulsive breathing associated with spasms in the truncal and respiratory muscles (Gračanin et al., 2014; Williams & Morris, 1996). There are widespread beliefs that emotional crying improves mood and is good for health (Bylsma et al., 2011; Cornelius, 1982); however, the empirical evidence has been mixed. When people recall crying episodes, they often report mood improvements, whilst in the laboratory crying consistently increases negative affect (Gračanin et al., 2015). This is called ‘the paradox of crying’. One of the primary hypothesised mechanisms for mood improvement is that tears act as a type of emotional relief valve, the production of tears is considered to release physiological arousal restoring physiological and emotional homeostasis. We would therefore expect a reduction of physiological arousal at the time of the tear. There are currently eleven empirical papers which have measured physiological correlates of crying and they consistently show crying is associated with a large physiological response as opposed to any reduction in physiological arousal (Gross et al., 1994; Hendriks et al., 2007; Ioannou et al., 2016; Kraemer & Hastrup, 1988; Mori & Iwanaga, 2017; Rottenberg et al., 2003; Sakuragi et al., 2002; Sharman, Dingle, Vingerhoets, et al., 2019; Wassiliwizky et al., 2017). However, in the majority of these studies it is unclear how many participants actually wept. This is particularly important because episodes of crying that are recalled as improving mood are intense and contain weeping. It may be the case that it is the process of shedding tears which acts to reduce physiological arousal. The purpose of this study is to examine whether weeping explains the paradox of crying using a broad range of psychophysiological techniques, including thermal imaging, heart rate variability, respiration rate and skin conductance to monitor the physiological profile during weeping.

Tears are an extremely powerful form of emotional expression linked to situations of loss and helplessness (Vingerhoets & Bylsma, 2016) and are mainly, although not exclusively, associated with emotions in the sadness family (Vingerhoets et al., 2000). The hypothesised *inter*individual function of tears is that they communicate our emotions to others to elicit social support (Balsters et al., 2013; Hendriks, Croon, et al., 2008; Provine et al., 2009; Vingerhoets et al., 2016). There are strong gender differences associated in crying behaviour with females showing more proneness, tendencies and actual frequency of crying episodes (Vingerhoets & Cornelius, 2001). This is often attributed to tears being seen as a sign of weakness or lack of masculinity (MacArthur & Shields, 2015) with males reporting more shame from crying (Becht & Vingerhoets, 2002). It is for these reasons weeping is often subject to cognitive mediation in the form of emotional suppression (Labott & Teleha, 1996). The general consensus is that it is the tear is the critical feature in social settings with other crying behaviours being less obvious social signals (Gračanin et al., 2014). From a physiological perspective, if tears are acting as an honest signal of emotional distress, we would expect weeping to be related to intense underlying affect and, by consequence, large physiological responses.

The hypothesised *intra*intervidual function of tears is that they are cathartic (Bylsma et al., 2011) or self-soothing (Gračanin et al., 2014). These two related, but not identical functions, suggest tears act as a way of abreacting strong emotions (catharsis) or reducing physiological arousal (self-soothing). It is through this reduction or release of negative affect that crying is purported to be beneficial to health (Gross et al., 1994). Folk psychological explanations often suggest crying is a way to relieve tension by 'letting the emotion out'. The empirical evidence for the cathartic effect of crying has been mixed and seems dependent on *when* and *how* the emotion is measured (Gračanin et al., 2015). Participants who kept a crying and mood diary for approximately two months indicated about 30% of crying episodes improved mood, compared to 61% where mood stayed the same and 10% where mood worsened. This is contrary to results in laboratory based crying where there is consistent and robust evidence that crying is associated increased heart rate, skin conductance, finger temperature, respiration rates, and bodily movements (Gross et al., 1994), face temperatures (Ioannou et al., 2016), facial muscles (Wassiliwizky et al., 2017), blood pressure (Hendriks et al., 2007), and pre-ejection period of heart rate (Hendriks et al., 2007). This is also reflected in subjective measures, criers report higher levels of sadness than non-criers (Gračanin et al., 2014). Overall, participants who cry in laboratories show increased physiological arousal and more intense feelings of sadness than non-crying participants.

There are some critical methodological differences between studies based on diaries and studies which take place in the laboratory that may explain the crying paradox. Laboratory studies tend to examine the short-term effects of low intensity crying, whereas diary studies are retrospective, have a longer time frame for measurement and normally include recollection of intense episodes of crying. There is evidence that the intensity of the crying episode is positively correlated with mood improvement (Bylsma et al., 2011). Therefore, it seems important to induce intense crying in the laboratory, including weeping, to assess whether intensity of crying explains the paradox. Inducing crying in the laboratory is notoriously difficult (Vingerhoets & Cornelius, 2001). Laboratory studies generally induce weak intensity crying, with watery eyes being the inclusion criteria to be counted as a crying episode (Gross et al., 1994; Hendriks et al., 2007; Kraemer & Hastrup, 1988; Marston et al., 1984; Mori & Iwanaga, 2017; Rottenberg et al., 2002, 2003; Sakuragi et al., 2002; Wassiliwizky et al., 2017). In laboratory based crying studies the success rate for inducing crying is poor, between 22% - 45%, with the majority showing watery eyes but not weeping. Social desirability is a major factor in whether someone will weep in the laboratory (Vingerhoets & Cornelius, 2001). However, a participant's ability to get immersed in the film will affect the intensity of the underlying affect (Ioannou et al., 2016), and their overall emotional expressivity will impact any emotional regulation (Gross & John, 1995). The crying rate is improved when experimenters specifically recruit participants who cry at films *and* let the participants choose their own film. This idiographic induction technique has achieved crying rates above 80%, with the majority of participants weeping (Ioannou et al., 2016). Therefore, not only does the idiographic induction technique induce more episodes of crying, it induces more intense episodes of crying.

Comparisons between laboratory induced crying which increases negative affect, and the crying people recall as improving mood is confounded by the intensity of crying episode. More specifically whether the crying episode is intense and includes weeping; laboratory studies rarely induce weeping, whilst the episodes of crying people are often intense and include weeping. To address whether weeping explains the paradox of crying, this study will focus on the physiological response when participants actually shed a tear. If weeping explains the paradox of crying and brings about physiological homeostasis, we would expect a reduction in physiological arousal at the time of tear production. We will use an idiographic induction technique (Ioannou et al., 2016) to induce the strong emotions required to produce tears. A large and comprehensive suite of physiological measurements will provide a psychophysiological picture of weeping, including thermal imaging, heart rate variability, respiration rates and skin conductance alongside subjective affect ratings.

3.3 Method

3.3.1 Ethics

Ethical approval was given by the Research Ethics Committee of the Faculty of Science, University of Portsmouth. The procedures were in line with the Declaration of Helsinki and the British Psychological Society code of human research ethics.

3.3.2 Participants

To increase the rate of weeping in the laboratory we specifically recruited participants on the basis they cry at sad movies. Participants were asked to indicate whether they agreed with the statement ‘I often cry whilst watching sad movies’ and a final sample of forty female participants that self-identified as criers were recruited from the University of Portsmouth student population and through word of mouth of the researchers. The participants were then quasi-experimentally split into two groups depending on whether they wept during the experimental session. This gave 20 weepers aged between 19-41 years old (*M* = 23.55 years, *SD* = 5.49) and 20 non-weepers aged between 18-33 years old (*M* = 21.70 years, *SD* = 4.12). Make-up can interfere with the thermal properties of the skin so participants were required to wear no or minimal make-up (Ioannou, Gallese, et al., 2014). All participants were also required to be free from any vasoactive substances that may interfere with physiological responding at the time of the experiment (Ioannou, Gallese, et al., 2014). Participants were excluded from participating if they had any neurological disorders or required corrective glasses to watch the videos; infrared light does not pass through the lens of the corrective eyewear.

3.3.3 Design

A mixed factorial design was used. The within subject factor was time with measurements taken over the duration of the weeping episode or sad scene. The between subject factor was whether the participant wept during the sad video. Therefore, allocation to the between subject factor was quasi-experimental. The physiological dependent variables were the face temperatures from six regions of interest (ROI), heart rate, two measures of heart-rate variability (SDNN & rMSSD), electro-dermal activity and respiration rates. We also measured subjective affect after each of the two films.

3.3.4 Materials

Physiology data acquisition. Facial temperatures were captured using a FLIR A655sc (FLIR©) thermal video camera with an uncooled FPA microbolometer (640 x 480 LWIR resolution). The A655sc has a spectral range of 7.5 - 14µm, temperature sensitivity of <30 mK with and an accuracy ± 2% of reading. The camera was placed 1 meter from the participants' face. The videos were captured at a sampling rate of 25Hz/fps. The camera was controlled and data recorded using FLIR ResearchIR (FLIR©) software in a control room attached to the experimental room.

Peripheral physiology, electrocardiogram (ECG), skin conductance level (SCL) and respiration rates (RR), were captured using a BioRadio™ system and BioCapture™ software from Great Lakes NeuroTechnologies©. The 16-bit raw signals were sampled at 1000Hz. Digital filters were applied post-experiment during the extraction of the data. The ECG was connected to the participant using EL204 ECG disposable pads (3M Red Dot™) using a 2-lead configuration. The leads were placed on either side of the chest below the medial portion of each collarbone. The SCL was recorded from the distal phalanges of the middle and ring finger of the non-dominant hand. A ground wire was placed on the back of the non-dominant hand. RR was captured using a Piezo electric respiratory effort belt (Braebon™) placed around the torso. Tears were marked by the experimenter using BioCapture™ during the sad film.

Questionnaires. The Creative Experiences Questionnaire (CEQ; Merckelbach, Horselenberg, & Muris, 2001) was used to measure fantasy proneness. The questionnaire has 25 statements such as "When I think of something cold, I actually get cold". Participants indicated which statements applied to them. A total fantasy proneness score was the sum of how many statements were indicated as applicable. The range of possible scores was 0-25 with higher scores indicating more fantasy proneness.

The Berkeley Expressivity Questionnaire (BEQ; Gross & John, 1995) is a 16 item scale to measure an individual's subjective assessment of their own emotional expressivity. Each item is answered using a 7-point Likert scale ranging from 1(strongly disagree) to 7 (strongly agree). The BEQ is separated into three separate factors: Negative Expressivity (6 items, score range 6-42), Positive Expressivity (4 items, score range 4-28), and Impulse Strength (6 items, score range 6-42). Scores were also combined to give a total expressivity score (16 items, score range (16-112). Higher scores indicated higher emotional expressivity.

Participants indicated their subjective levels of emotion. This was completed on three occasions, when they arrived at the laboratory, and after each video. The instruction was: “Please indicate how much you feel the emotion currently” followed by a ten point scale (1 low – 10 high). There were 9 emotional categories: happy, sad, angry, boredom, interest, fear, amusement, disgust, and relaxation.

Stimulus materials. An emotionally neutral video was used as a ‘vanilla’ baseline control condition (Jennings et al., 1992). Five minutes were selected from “The private life of barn owls” (Cobham, 1977). The film contained an explanation on barn owl hearing, wing structure and flight patterns. Participants watched from 6.12 – 11.12 minutes, this scene was selected as it was more informative than dramatic, reducing the probability of inducing an emotion.

An idiographic approach was used to induce weeping. Participants were asked in advance of the experiment to select three or more sad scenes from films which had previously made them cry. Participants had a completely free choice of films and scenes, however, common choices emerged. Table 3.1 shows the films and scenes that were used and how many wept whilst watching them. The films were started 5-10 minutes prior to their chosen sad scene to allow the participant enough time to become emotionally involved in the film. Participants were allowed to choose at what point they would like the film to start. The films continued for 5-10 minutes after the sad scene so in total ran for 10-20 minutes.

Table 3.1. Films used during the experiment including the sad scene and how many wept during the scene

Film	Sad Scene	Times watched (*n*)	Number of weepers (*n*)
Marley and Me	Marley dies	14	7
The Notebook	Noah and Allie die	4	2
Up	Opening Credits	3	1
My Sister's Keeper	Kate reads a memory book	3	1
A Fault in our Stars	Augustus says his cancer has returned	2	1
Titanic	Elderly couple die	2	2
Green Mile	John Coffey is taken to executed	2	2
Monsters Inc.	Sulley says goodbye to Boo	2	0
Kal Ho Na Ho	Aman dies	1	1
The Land Before Time	Littlefoot's grandmother dies	1	1
Timbuktu	Kidane and his wife die	1	1
The Boy in the Striped Pyjamas	Bruno and Shmuel die	1	1
The Mist	David Drayton kills family	1	0
Amazing Spiderman 2	Gwen Stacey dies	1	0
Fruitvale Station	Grant dies	1	0
Harry Potter and the Half-Blood Prince	Dumbledore dies	1	0

3.3.5 Procedure

The study was conducted in a sound attenuated psychophysiological laboratory consisting of an experimental room and an adjoined control room. The experimental room was windowless, and temperature controlled. The participants were sat at a desk with a computer monitor approximately 0.75m away. A webcam was placed on the monitor to capture the participants responses whilst watching the sad film (See Chapter five). A laptop was connected to the monitor to play the stimulus films. The infrared camera was placed behind the desk, on a tripod slightly to the left of the monitor so there was an unobstructed view of the participants' face. The camera was approximately 1 meter from the participant but controlled remotely. The BioRadio™ signal recorder was located next to the participant and controlled remotely.

Upon arrival, participants acclimatised to the room temperature for 30 minutes (Ioannou et al., 2014). During this time period the physiological sensors were attached and calibrated and the participant filled out the BEQ, CEQ and a demographics questionnaire. The participants then watched the sad or neutral film (counter balanced). Participants were then given a 10 minute colouring task between stimulus films to allow their physiology to return to baseline levels (Jennings et al., 1992). They then watched the remaining stimulus film. Overall the participation lasted around one hour.

3.3.6 Data Extraction and Analyses

Synchronising the sad films. The use of idiographic stimuli for the sad condition meant that for the purposes of analysis we had to establish a common anchor that would be consistent across participants. For criers, we used the first tear as the anchor point and analysed two minutes preceding the first tear and two minutes after the first tear. For non-criers, we used the start of their chosen sad scene as the central point and measured two minutes prior and two minutes post the sad scene. The majority of weepers (*n* = 14) cried at their chosen sad scene +/- 30 seconds with three weeping earlier and three weeping at a later point in the film.

Extraction of thermal data. The thermal data were analysed using FLIR Tools for PC (FLIR®). The thermal data were checked for any high frequency changes which may indicate technical issues. For analysis, picture frames were extracted every 60 seconds +/- 2 seconds. The best frame within the +/- 2 second tolerance was used to limit measurement noise and artefacts (Ioannou et al. 2014). For each picture frame, the average temperature was extracted from six ROI (Ioannou et al., 2014). Square shapes were used for the forehead and maxillary area, circular shapes for nose tip, periorbital and cheek, and an oval shape for the chin, (see figure 3.1). The size of the ROIs was kept stable throughout each video unless an obstruction, such as hair, changed the size of available skin. Between participants, the size of the ROI changed depending on the morphology of the face although as a rule the ROI was as large as possible to give the most reliable average.

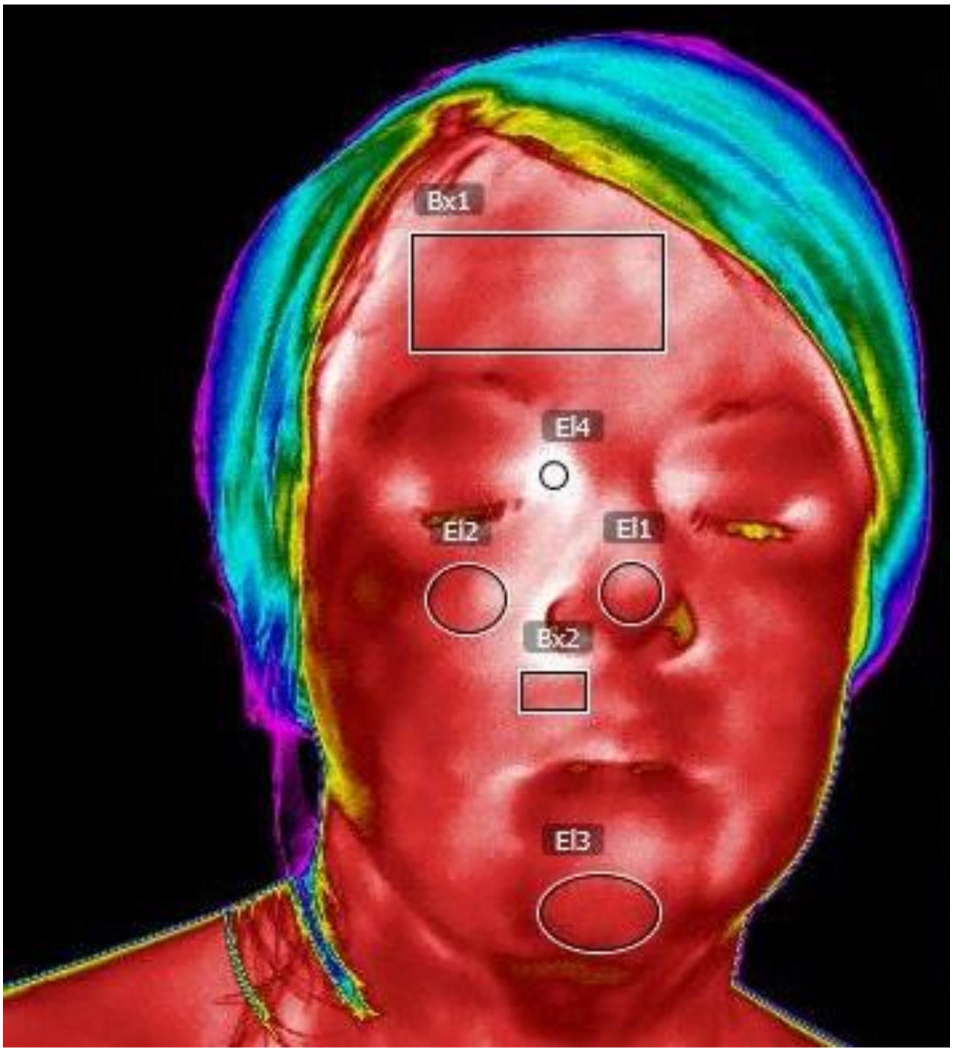

Figure 3.1. Six ROI used to extract facial temperature (Bx1 forehead, Bx2 maxillary, El1 nose-tip, El2 cheek, El3 chin, and El4 periorbital).

Reliability of thermal data. To check for reliability in extracting the thermal data a second rater extracted data from six of the participants (20%). There was a strong agreement on the average temperature from each 15 second measurement ($\alpha = .997$ [based on 444 observations]). This suggests that data extracted from the thermal videos shows little variation due to the coder. This was further explored by individual ROI with strong agreement in nose tip ($\alpha = .999$), forehead ($\alpha = .986$), maxillary (α = .978), cheek (α = .982), and chin (α = .994). However, the periorbital showed poor agreement (α = .445) the variation in ratings was on average 0.2◦C (95%CI [0.28 : 0.11]), therefore, any periorbital results will be interpreted with caution. The poor agreement is likely due to the small size of the periorbital ROI.

Extraction of cardiorespiratory and electrodermal physiological data. The ECG, SCL, & RR raw signals were processed in VivoSense™. The software automatically down sampled the signals for ease of processing. The VivoSense™ heart rate variability module was then used to mark the ECG for R-waves, identify artefacts, and identify ectopic beats. This signal was then visually inspected and corrected as necessary. One minute epochs were then created. There were four epochs taken from the sad video using either the first tear (weepers) or the beginning of the sad scene (non-weepers) as a central point. The average scores for HR, SCL, SDNN, rMSSD, & RR were calculated for each time epoch.

3.4 Results

3.4.1 Differences between weepers and non-weepers at baseline.

The study employed a quasi-experimental approach to group allocation. All participants underwent the same conditions, however, they were split by whether they wept or not. To check for systematic group differences at baseline we conducted independent group *t*-tests on personality measures (pre experiment), subjective emotions (after a vanilla baseline) and physiological measures (during the vanilla baseline) taken during the final minute of the baseline film. Tables 3.2 show that weepers rated their negative expressivity as significantly higher than the non-weepers with a large effect. They did not significantly differ in their positive expressivity, fantasy and emotional impulsivity. There were no differences in subjective emotions or physiology during the vanilla baseline (table 3.3).

Table 3.2. Differences in personality measures between weepers and non-weepers.

Questionnaire	Scale	Weepers	Non-weepers	*p*	*d*
BEQ	**Negative Expressivity**	**27.95 (6.53)**	**21.1 (6.16)**	**.002**	**1.08**
	Positive Expressivity	23.95 (3.97)	22.05 (2.81)	.089	0.55
	Emotional Impulse	35.1 (5.85)	32.25 (7.2)	.178	0.43
CEQ	Fantasy Proneness	9.2 (3.27)	10.65 (4.65)	.261	0.36

Note. Significant results in bold

Table 3.3. Differences in physiology and subjective emotions between weepers and non-weepers during the 'vanilla' baseline.

Measure		Weepers	Non-weepers	*p*	*d*
Cardiorespiratory	Heart rate (bpm)	80.57 (11.42)	79.53 (7.21)	.73	0.11
	SDNN (ms)	49.31 (25.21)	48.61 (16.37)	.92	0.03
	rMSSD (ms)	44.62 (29.16)	44.23 (16.37)	.96	0.02
	Respiration rate (bpm)	16.78 (3.07)	17.97 (2.58)	.21	0.42
Electrodermal	SCL (μS)	7.73 (3.16)	9 (4.12)	.29	0.33
Facial Temperatures	Forehead (ºC)	34.67 (.46)	34.64 (.49)	.82	0.06
	Maxillary (ºC)	34.87 (.63)	34.62 (.97)	.34	0.31
	Nose tip (ºC)	31.73 (2.54)	31.5 (3.21)	.62	0.08
	Cheek (ºC)	33.97 (.98)	33.55 (1.27)	.24	0.37
	Chin (ºC)	33.5 (.65)	33.49 (1.13)	.97	0.01
	Periorbital (ºC)	35.96 (.22)	35.91 (.35)	.59	0.17
Subjective Emotion (1 low-10 high)	Happy	5.4 (2.41)	5.95 (1.82)	.42	0.26
	Sad	2.65 (1.79)	2.25 (1.62)	.46	0.23
	Anger	1.3 (.57)	1.3 (.92)	>.99	<.01
	Fear	1.1 (.31)	1.45 (1)	.14	0.47
	Boredom	2.45 (2.21)	3.15 (2.62)	.37	0.28
	Interest	6.15 (2.83)	5.45 (2.11)	.38	0.28
	Amusement	4.3 (2.45)	3.95 (2.43)	.65	0.14

3.4.2 Facial Temperatures during the sad film

To investigate differences in facial temperatures between weepers and non-weepers a 2 (Wept or not) x 5 (Time) mixed factorial MANOVA was conducted on average temperature in each of the six ROI. The within groups factor was time of measurements with one measurement taken every minute from 120 seconds prior until 120 seconds post tear. The between groups factor was whether the participant wept or not. There was a multivariate main effect of time $\lambda = .15$, F (24, 11) = 2.63, $p = .05$, $\eta_p^2 = .85$ with a large effect size, temperature increased over time. There was a significant multivariate effect of weeping status, $\lambda = .62$, F (9, 29) = 2.99, $p = .02$, $\eta_p^2 = .38$, weepers got hotter than non-weepers. There was also a multivariate interaction $\lambda = .08$, F (24, 11) = 5.37, $p = .003$, $\eta_p^2 = .92$, weepers got hotter than non-weepers but only after the tear. Table 3.4 shows the univariate ANOVA's summary statistics. In summary, temperature increased in all regions of interest for both weepers and non-weepers, however, *after* the tear weepers had a significantly larger temperature increase (Figure 3.2).

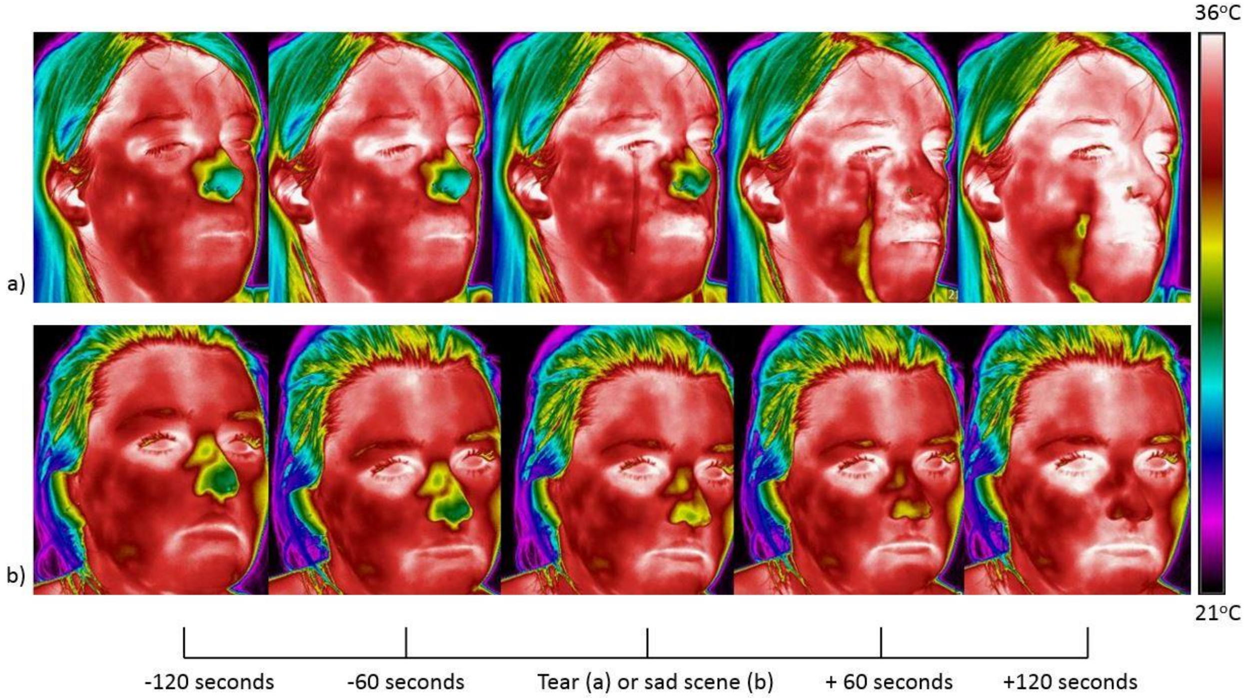

Figure 3.2. Facial temperatures in a weeper (a) and a non-weeper (b)

Table 3.4. Univariate ANOVA summary statistics for facial temperatures as a function of time and whether the participant wept.

Measure	Time	Weepers	Non-Weepers		Summary Statistics			
		M (SD)	M (SD)	*p*		F (df)	P	N
Nose Tip	**-120 sec $_{a}$**	**31.2 (2.63)**	**29.25 (2.31)**	**.04**	**Time**	**33.47 (1.35, 45.83)**	**<.001**	
	-60 sec $_{a}$	31.36 (2.67)	29.64 (2.65)	.1	**Weeping**	**11.38 (1, 34)**	**.002**	
	Tear/Sad $_{b}$	**32.37 (2.29)**	**30.27 (2.81)**	**.04**	**Time x Weeping**	**4.87 (1.35, 45.83)**	**.023**	
	+ 60 sec $_{c}$	**34.25 (1.4)**	**30.76 (3.17)**	**<.001**				
	+ 120 sec $_{d}$	**34.75 (1.42)**	**31.11 (3.18)**	**<.001**				
Forehead	-120 sec $_{a}$	34.71 (.53)	34.54 (.38)	.29	**Time**	**32.82 (1.56, 53.04)**	**<.001**	
	-60 sec $_{a}$	34.72 (.55)	34.54 (.42)	.27	Weeping	2.73 (1, 34)	.11	
	Tear/Sad $_{b}$	34.85 (.6)	34.63 (.37)	.19	**Time x Weeping**	**5.85 (1.56, 53.04)**	**.009**	
	+ 60 sec $_{c}$	**35.01 (.62)**	**34.68 (.32)**	**.06**				
	+ 120 sec $_{d}$	**35.12 (.67)**	**34.7 (.32)**	**.02**				
Maxillary	-120 sec $_{a}$	34.64 (.81)	34.24 (.86)	.18	**Time**	**24.88 (1.55, 52.74)**	**<.001**	
	-60 sec $_{a}$	34.66 (.83)	34.33 (.95)	.28	Weeping	3.55 (1, 34)	.07	
	Tear/Sad $_{b}$	34.89 (.72)	34.56 (.93)	.24	Time x Weeping	1.96 (1.55, 52.74)	.16	
	+ 60 sec $_{c}$	**35.32 (.59)**	**34.77 (.95)**	**.05**				
	+ 120 sec $_{c}$	**35.59 (.51)**	**34.82 (.98)**	**.006**				
Cheek	-120 sec $_{a}$	33.82 (1.16)	33.12 (1)	.06	**Time**	**31.06 (1.43, 48.76)**	**<.001**	
	-60 sec $_{b}$	33.87 (1.14)	33.24 (.95)	.08	**Weeping**	**5.81 (1, 34)**	**.02**	
	Tear/Sad $_{c}$	**34.07 (1.07)**	**33.37 (.98)**	**.05**	Time x Weeping	3.49 (1.43, 48.76)	.053	
	+ 60 sec $_{d}$	**34.45 (.96)**	**33.49 (1.03)**	**.007**				
	+ 120 sec $_{e}$	**34.66 (1)**	**33.61 (1.12)**	**.005**				
Chin	**-120 sec $_{a}$**	**33.74 (.97)**	**33 (.76)**	**.02**	**Time**	**17.78 (2.22, 75.56)**	**<.001**	
	-60 sec $_{a}$	**34 (.94)**	**33.02 (.75)**	**.01**	**Weeping**	**8.8 (1, 34)**	**.005**	
	Tear/Sad $_{a}$	**33.81 (.95)**	**33.06 (.75)**	**.01**	Time x Weeping	2.11 (2.22, 75.56)	.12	
	+ 60 sec $_{b}$	**34 (.87)**	**33.16 (.74)**	**.003**				
	+ 120 sec $_{b}$	**34.14 (.81)**	**33.19 (.74)**	**.001**				
Periorbital	-120 sec $_{a}$	36.06 (.4)	35.9 (.29)	.16	**Time**	**18.71 (2.64, 89.62)**	**<.001**	
	-60 sec $_{ab}$	36.13 (.39)	35.92 (.28)	.07	**Weeping**	**6.75 (1, 34)**	**.014**	
	Tear/Sad $_{b}$	**36.21 (.35)**	**35.97 (.27)**	**.03**	**Time x Weeping**	**3.79 (2.64, 89.62)**	**.017**	
	+ 60 sec $_{c}$	**36.34 (.37)**	**36.12 (.28)**	**.005**				
	+ 120 sec $_{c}$	**36.44 (.42)**	**36.23 (.39)**	**.001**				

Note. Times in each ROI that do not share a subscript differ significantly (p <.05). All comparisons used a Sidak adjustment. Significant results in bold.

3.4.3 Cardiorespiratory and electrodermal responses during the sad film

A series of 2 (weeping status [wept, didn't weep], between-subjects factor) x 4 (time epoch, within-subjects) mixed factorial ANOVAs were conducted on the mean levels during the one minute time epochs. There were two time epochs preceding the tear and two after the tear. The ECG from one of the weepers was unusable and they were excluded from the heart rate and heart rate variability analysis. Two of the weepers respiration rate measures were also unusable and they were excluded from the respiration rate analysis. Overall weeping had very little effect of the cardio respiratory and electrodermal measures. Table 3.5 shows that there was a significant main effect of time on HR, although post-hoc pairwise comparisons failed to identify any significant differences between the time periods. Non-weepers had a significantly higher SCL than weepers two minutes post tear although the ANOVA didn't find any main effects or interactions for SCL. All other main effects and interactions were non-significant.

Table 3.5. Peripheral physiological levels as a function of time and whether the participant wept or not.

Measure	Time	Weepers	Non-Weepers		Summary Statistics			
		M (SD)	M (SD)	*p*		F (df)	*p*	η^2
Heart rate	-2 Min	87.86 (15.23)	84.03 (9.67)	.35	**Time**	**3.75 (2.26, 83.64)**	**.023**	**.09**
	-1 Min	90.48 (15.2)	85.54 (12.41)	.27	Weeping	.67 (1,37)	.42	.04
	+1 Min	91.74 (13.85)	87.19 (16.15)	.35	Time x Weeping	1.34 (2.26, 83.64)	.47	.03
	+2 Min	89.33 (15.87)	88.46 (14.47)	.86				
SDNN	-2 Min	50.6 (22.85)	50.33 (22.96)	.97	Time	1.58 (2.31, 85.47)	.2	.04
	-1 Min	51.72 (26.42)	54.01 (18.32)	.76	Weeping	.08 (1, 37)	.78	.00
	+1 Min	59.45 (25.33)	53.15 (22.03)	.41	Time x Weeping	.97 (2.31, 85.47)	.4	.03
	+2 Min	55.37 (30.79)	51.84 (21.98)	.68				
rMSSD	-2 Min	40.95 (27.44)	39.49 (16.41)	.84	Time	1.09 (2.62, 96.84)	.36	.03
	-1 Min	38.04 (25.20)	41.58 (19.14)	.62	Weeping	.02 (1, 37)	.88	.00
	+1 Min	40.88 (25.99)	41.27 (16.39)	.96	Time x Weeping	2.60 (2.62, 96.84)	.06	.07
	+2 Min	46.31(35.08)	39.58 (15.42)	.44				
SCL	-2 Min	10.25 (3.75)	9.34 (4.87)	.52	Time	2.71 (2.02, 76.64)	.07	.07
	-1 Min	10.51 (3.73)	9.71 (4.42)	.54	Weeping	.44 (1, 38)	.51	.01
	+1 Min	10.96 (3.92)	9.92 (4.96)	.41	Time x Weeping	.26 (2.02, 76.64)	.77	.01
	+2 Min	10.61 (3.87)	9.92 (4.96)	.63				
Respiration	-2 Min	16.88 (4.05)	18.21 (4.09)	.32	Time	2.12 (2.61, 93.77)	.11	.06
	-1 Min	16.16 (3.95)	17.71 (3.3)	.16	Weeping	3.67 (1, 36)	.06	.09
	+1 Min	15.93 (2.98)	17.75 (4.11)	.13	Time x Weeping	1.27 (2.61, 93.77)	.29	.03

+2 Min	**14.84 (2.02)**	**17.87 (3.58)**	**.03**

Note. All comparisons used a Sidak adjustment.

3.4.4 Correlations between facial temperatures and traditional psychophysiological measures.

To check for response coherence, facial temperatures were correlated with HR, HRV, RR, and SCL. This resulted in 120 correlations (5 systems x 6 ROI x 4 time points), in this instance a Bonferroni correction is not appropriate (Nakagawa, 2004). Therefore, the following correlations should be interpreted as exploratory only. Respiration rates the minute proceeding the tear were significantly negatively correlated with periorbital and forehead temperatures with a moderate effect size (see table 3.6). All other correlations were non-significant (n = 112).

Table 3.6. Correlation between respiration rates 60s pre-tear with forehead and periorbital temperatures

	Forehead		Periorbital	
Time	*r*	*p*	*r*	*p*
-120s	-.46	.003	-.32	.048
-60s	-.48	.002	-.38	.02
+60s	-.47	.003	-.43	.007
+120s	-.46	.003	-.45	.005

3.4.5 Subjective emotional differences between weepers and non-weepers after the sad film

We compared the subjective emotion ratings of weepers and non-weepers after the sad film. Table 3.7 shows weepers were significantly less relaxed, happy, and interested than non-weepers and significantly more sad and disgusted. The associated effect sizes were all medium or large.

Table 3.7. Differences in subjective emotions between weepers and non-weepers after the sad film.

Subjective Emotion (1 low-10 high)	Weepers Mean *(SD)*	Non-weepers Mean *(SD)*	*p*	*d*
Relaxation	**2.9 (1.71)**	**5.25 (1.45)**	**<.001**	**1.48**
Sad	**8.75 (1.12)**	**7.3 (1.72)**	**.003**	**1.00**
Amusement	1.55 (1)	3.45 (2.56)	.067	0.98
Happy	**2.35 (1.18)**	**3.75 (2.05)**	**.013**	**0.84**
Interest	**5.1 (2.26)**	**6.55 (2.04)**	**.040**	**0.67**
Fear	2.35 (1.95)	1.45 (.76)	.087	0.61
Boredom	1.1 (.45)	1.95 (2.11)	.093	0.50
Disgust	**2.15 (1.87)**	**1.55 (1)**	**.005**	**0.40**
Anger	2.4 (2.19)	1.9 (1.33)	.339	0.28

Note. Significant results in bold

3.4.6 Relationship between subjective emotions and physiology

Relationships between subjective emotions and physiology were further explored by correlating the physiological variables 120 seconds post tear with subjective emotion ratings taken after the sad film. There were a total of 99 correlations made, in this instance a Bonferroni correction is not appropriate (Nakagawa, 2004). Therefore, the following correlations should be interpreted as exploratory only. Hotter temperatures in the nose tip, maxillary and cheek were associated with increased sadness and decreased happiness, interest, relaxation, and amusement. Forehead temperatures had a negative relationship relaxation, whilst chin temperatures were negatively related to interest, relaxation and amusement. Table 3.8 shows the correlations were moderate in effect size. Correlations between the subjective emotion scores and two-minute post tear scores for each peripheral psychophysiological measure found there was very little association between subjective emotions and peripheral physiology. There was a medium negative relationship between HR and interest scores, a medium negative correlation between RR and sadness and a medium negative correlation between SCL and happiness.

Table 3.8. Correlations between subjective emotions after the sad film and facial temperatures 120 seconds post tear.

		Emotions								
		Happ.	Sadness	Fear	Anger	Interest	Bored	Disgust	Relax	Amuse.
Face Temperatures	Nose Tip	**-.44****	**.48****	.21	.001	**-.38***	.003	.003	**-.50****	**-.44****
	Forehead	-.13	.22	.05	-.17	-.19	-.13	-.02	**-.42****	-.24
	Maxillary	**-.35***	**.35***	.05	-.10	**-.50****	.14	-.03	**-.38***	-.31
	Cheek	**-.38***	**.35***	.12	-.19	**-.45****	-.09	-.14	**-.43****	**-.43****
	Chin	-.26	.28	.25	.03	**-.33***	-.08	.22	**-.43****	**-.33****
	Periorbital	-.18	.18	.20	.14	-.27	-.04	.28	-.32	-.26
Cardio-respiratory	Heart Rate	-.12	.24	-.13	-.14	**-.41***	-.14	-.21	.06	-.17
	SDNN	.13	-.04	-.04	-.11	.30	.12	-.02	-.01	.07
	rMSSD	.03	-.07	-.04	-.09	.25	.03	-.02	-.15	-.04
	Respiration	.23	**-.48****	-.30	-.13	.07	.09	-.27	**.35***	**.37***
Electrodermal	SCL	**-.31***	.25	.15	.17	-.24	-.24	.26	-.21	-.20

Note. Significant results in bold, * significant at $p < .05$, ** significant at $p < .001$

3.5 Discussion

We found weeping was associated with very large increases in facial temperatures. Temperatures, after weeping, reached between 35°C to 36°C, with a mean temperature increase in the nose region of 3.5°C. This is an extremely large change and considerably more than the .5°C considered as the minimum temperature change required to be considered a meaningful response (Ioannou et al., 2016; Ioannou, Gallese, et al., 2014). Whilst both weepers and non-weepers had increased facial temperatures, the weepers got hotter than non-weepers after the start of weeping, in all ROI. The thermal response happens in the absence of any major responses in cardiorespiratory or electrodermal systems. Furthermore, none of the cardiorespiratory or electrodermal measures differed between weepers and non-weepers. Consistent with the current literature, weepers reported more negative affect and higher arousal compared to non-weepers. The subjective affect ratings correlated strongly with facial temperatures but not with either the cardiorespiratory or electrodermal indices. We feel this is a particularly important finding because there is often very little coherence between physiological response and subjective affect ratings (Mauss et al., 2005).

3.5.1 Facial Temperatures during weeping

During the sad scene the facial temperatures of both weepers and non-weepers in all ROIs increased over three distinct time phases: pre-tear, tear, and post tear. However, after tear production weepers got much hotter than non-weepers. The temperature changes associated with weeping were consistently large with the mean change (3.5 ^{o}C) in the nose tip representing one of the largest changes in the literature on the thermal response in emotion inductions. The nose is often the ROI associated with the largest thermal variations (Ioannou, Gallese, et al., 2014) and the temperature increase in this study is far larger than all of the previously reported temperature increases during emotion inductions (Ioannou et al., 2016; Ioannou, Gallese, et al., 2014; Merla & Romani, 2007; Wang et al., 2010). The rise in facial temperature is caused by an increased subcutaneous blood flow through vasodilation of the blood vessels (Ioannou, Gallese, et al., 2014). The increase in arterial blood into the tissue raises the surface temperature and reddens the tissue (Ioannou et al., 2017). To what degree this reddening in weeping is perceivable by others has currently not been studied, but skin reddening does seem to aid emotion recognition (Thorstenson et al., 2019), and effect judgements of health (Stephen et al., 2009).

The use of facial temperatures as an index for ANS activity is relatively modern compared to more classic measures such as HR. Therefore, the data on relationship between emotions and facial temperature is quite sparse (see Ioannou, Gallese, et al., 2014, for a review). Temperature increases in the face are usually associated with social emotions, such as guilt and shyness, regardless of the valence of the emotion (Ebisch et al., 2012; Hahn et al., 2012; Ioannou et al., 2017). Whilst nose cooling is associated with negative emotions such as fear and stress, in both human and non-human primates (Chotard et al., 2018; Ebisch et al., 2012; Engert et al., 2014; Ioannou, Morris, et al., 2014; Nakayama et al., 2005; Pavlidis et al., 2001). Therefore, the thermal response during weeping has more commonalities with social interactions than negative affect. This makes sense when we consider weeping as a social tool used to facilitate social bonding (Gračanin, Krahmer, et al., 2018; Hasson, 2009; van de Ven et al., 2017; Vingerhoets et al., 2016; Zickfeld et al., 2018)). Whether the temperature rises in face are functional in the social engagement is less well understood. One possible explanation is in the colour changes associated with increased blood flow are perceivable and act as an honest signal to others about our subjective wellbeing (Stephen et al., 2009). In this sense, the additional blood flow in the face during weeping may work similarly to blushing where we also find temperature increases and reddening of the skin (Ioannou et al., 2017). This theory would also fit with fear and anxiety where there is often a linguistic association with pallor (Montoya et al., 2005). The next step to understand whether thermal changes have a signal value would be to empirical test whether the reddening is perceivable by observers and whether it impacts judgements of affect.

Temperature rises in the face during weeping have been found previously (Ioannou et al., 2016), however, we also found temperature rises in the non-weeping control group. The non-weepers were still reacting to stimuli in a similar way to the weepers, with less magnitude. The obvious explanation for this is that these participants still cried but did not weep. For instance, some non-weepers had watery eyes whilst others did not, some non-weepers slowed their breathing, indicating sobbing, whilst others did not. What is not clear from our data is how intensely the crying behaviour was in the non-weeping participants. This is important if we consider crying an ‘umbrella’ term for a range of behavioural responses and weeping as a term for to shedding tears. Whilst other behaviours in the crying cluster, such as sobbing, may be related to physiological recovery (Gračanin et al., 2014; Sharman, Dingle, Vingerhoets, et al., 2019), weeping functions on an interindividual level as a social signal to elicit support (Vingerhoets & Cornelius, 2001). For future studies it would be important to measure the intensity of different crying behaviours to see whether the individual behaviours correlate strongly with inter- or intraindividual functions. Our results do show that weeping is associated with a large increase in face temperatures and weeping has a dramatic effect over and above any other crying behaviour. Overall, thermal imaging is an effective way of measuring autonomic responses. With the face being a major communicator of affect (Fridlund, 2014), facial thermal imaging may be particularly useful for measuring affective behaviour with a strong communicative function such as weeping.

3.5.2 Cardiorespiratory and electrodermal physiology and weeping.

Watching the sad scene had a very small effect on HR, HRV, RR and SCL. HR increased during the sad scene for both weepers and non-weepers. However, post-hoc comparisons did not reveal any significant differences between the four-time measurements. The increased HR is consistent with previous studies on crying and has been linked to SNS activity associated with increased arousal (Gross et al., 1994; Hendriks et al., 2007; Kraemer & Hastrup, 1988; Mori & Iwanaga, 2017; Rottenberg et al., 2002, 2003; Sharman, Dingle, Vingerhoets, et al., 2019; Wassiliwizky et al., 2017). Given that the SNS is primarily a system to mobilise an organism (Stemmler, 2004), functionally this increased SNS activity could be the embodied indicator to move the weeper/non-weeper to resolve the current situation. Despite finding elevated HR across both groups during the sad scene there was no difference between weepers and non-weepers at any of the time points. This is contrary to previous research which has found crying to be associated with increased HR compared to non-crying (Gross et al., 1994). The remaining physiological indices: HRV, RR, SCL were not significantly affected by weeping. The difference between weepers and non-weepers approached significance for HRV and RR. Whilst the increase in SCL over time also approached significance. This data are not consistent with previous research which suggests we should have found increased HRV in post tear measurements previously reported (Rottenberg et al., 2003), reduced RR (Gross et al., 1994) and increased SCL (Gross et al., 1994). We believe the reason we have failed to replicate these differences is because of the distinction between weeping and crying. Whilst previous studies have grouped participants by any crying behaviour vs. no crying behaviour, we have separated participants by shed a tear vs. not shed a tear. Therefore, in previous studies the non-crying group contained participants that showed minimal responses to the sad stimuli, whereas the non-weeping group in this study included all crying behaviours except tears. This means in some of the previous studies the separation is between those who reacted to the stimuli vs. those who didn't. In these instances, there are between group differences. Our separation is based on intensity whereby both groups are reacting to the stimuli therefore the group differences are reduced.

Overall, in this study and previous studies there is some indication that there is both cardiorespiratory and electrodermal responses to weeping (Gross et al., 1994; Sharman, Dingle, Vingerhoets, et al., 2019), however, in a laboratory setting the effect sizes are small. This explanation fits well with the current understanding of the psychophysiology of emotion (Kreibig, 2010; Siegel et al., 2018). This is contrary to the thermal responses which were consistently large and distinguished between weepers and non-weepers. Coupled with the flexibility offered by using infra-red cameras instead of contact based electrophysiology, thermal imaging may be a more appropriate technique for measuring affective physiological responding.

3.5.3 Coherence of physiological responses.

To check for physiological coherence (the coordination and association of the responses as the emotion develops over time; Mauss et al., 2005), a series of correlations were performed on facial temperatures with cardiorespiratory and electrodermal measurements. The only significant correlation was a negative relationship between pre tear respiration rates with both forehead and periorbital temperature. The relationship between RR and forehead and periorbital temperatures may be a product of emotional suppression. Although not asked to suppress tears, the laboratory creates an environment which would be associated with tear suppression (Simons et al., 2013; Vingerhoets & Bylsma, 2016). The participants are in the presence of a stranger and in a professional setting, both of which provide strong social pressures to inhibit weeping (Vingerhoets & Cornelius, 2001). The suppression of tears is a cognitively demanding act (Gross, 1998), which may include slowed (diaphragmatic) breathing to reduce arousal (Grossman, 1983) whilst cognitive exertion has been found to increase forehead and periorbital temperatures (Or & Duffy, 2007). However, emotional suppression was not directly measured in this experiment *and* the relationship between suppression of weeping and physiology is poorly understood despite being a very common event in naturalistic settings (Gross, 2013; Labott & Teleha, 1996; MacArthur & Shields, 2015; Simons et al., 2013). Further work is needed to understand how tear suppression impacts physiology, there is evidence that the suppression of emotional expressions is linked to both increased physiological responses (Gross, 1998; Gross & Levenson, 1997) and reduced physiological responses (Drummond & Quah, 2001; Gottman, 1993).

3.5.4 Subjective affect and weeping.

Participants who wept indicated that they felt sadder and less relaxed and less happy than participants who didn't weep, with very large effect sizes. Weepers also indicated being slightly more disgusted and less interested that non-weepers. The findings on subjective affect is consistent with the previous literature, criers report being sadder than non-criers (Gross et al., 1994; Marston et al., 1984; Mori & Iwanaga, 2017; Rottenberg et al., 2002). Whilst sadness was the most intensely experienced emotion, the largest difference between weepers and non-weepers was for relaxation. After the sad film weepers were considerably less relaxed than non-weepers. This study is the first to find levels of subjective relaxation may be a key in the experience of weeping. This is especially interesting in light of cathartic theories of weeping which would hypothesise increased relaxation from stress reduction (Bylsma et al., 2008). The data provides strong support for the increased arousal hypothesis for both negative affect and physiological arousal. Despite increasing negative affect, people do report enjoying watching sad films including those which induce weeping (Schramm & Wirth, 2010). Being 'moved' emotionally seems to be an aesthetically pleasurable experience regardless of the valence of the affect (Hanich et al., 2014; Landmann et al., 2019).

Facial temperatures showed strong coherence with the subjective emotions scores. These were particularly strong for relaxation and interest scores as opposed to the 'basic' emotions; however, five of the nine emotions showed a moderate correlation with facial temperatures. The negative relationship between face temperatures and relaxation seems to suggest general arousal is a key underlying factor if we consider relaxation as the inverse of arousal. Therefore, face temperatures are increasing with arousal levels. Lastly the negative relationship between interest and face temperatures can generally be explained by the idea that those lacking interest in the film were probably not engaging or becoming physiologically aroused. Temperature was also positively related to negative affect. There were no correlations between post tear temperatures and fear, anger, boredom and disgust, which was expected given that the films did not induce these emotions in any intensity. Although, happiness and amusement were also not induced, it is likely that these were considered the inverse of sadness, which was induced strongly in the participants. The similarity in size of correlations between happiness and amusement compared to sadness alludes to this. The coherence between facial temperatures and subjective emotions was very strong given the lack of coherence between more traditional psychophysiological measures and affect that is often found in the literature. The size of the correlations were similar to those found between facial expressions and subjective affect (Mauss et al., 2005; Reisenzein et al., 2013). It should also be noted that due to the large number of correlations performed there is a risk of type 1 errors. Therefore, more confirmatory research will need to be completed to check for false positives in the coherence between facial temperatures and subjective affect.

There was very little coherence between subjective emotions and cardiorespiratory and electrodermal physiology. Post tear HR was moderately negatively correlated with interest scores, the more engaged with the film the participant the lower their post tear heart rate. There is a strong connection in cognitive psychology between watching videos and reductions in heart rate which explains this relationship (Lacey et al., 1963). Post tear RR correlated negatively with sadness, which is likely a product of sobbing behaviours in the participants who got saddest (Gračanin et al., 2015). Finally, there was a small to medium negative correlation between post tear SCL and happiness. Those who were least happy showed the highest SCL. This is likely a product of the higher SCL in weepers who also felt less happy post tear. The general lack of coherence between peripheral physiology and subjective emotions is not uncommon in the literature (Mauss et al., 2005). It is often used in the wider debate about 'what emotions are' to argue against basic emotion theory (Barrett, 2006).

3.5.5 Methodological considerations

This study induced weeping in the laboratory using an idiographic induction technique and achieved a high rate of weeping (50%) starting only approximately five minutes before the sad scene. This is a far shorter time frame than has been previously used but weeping rates can be increased to over 80% by using 30 minutes preceeding the scene (Ioannou et al., 2016). Furthermore, despite giving the participants free choice of films some common choices emerged as excellent 'tear jerkers'. Films such as Marley and Me, The Notebook, and Titanic were included in the majority of participant choices. The biggest methodological issue in using the idiographic induction technique is that it makes comparisons between participants difficult. The differences in stimuli film mean that there is very little temporal consistency whilst some films built up the levels of emotional tension slowly some unfolded over a shorter time span. However, because there were some films that were picked consistently, it may be possible to allow participants some freedom of choice whilst minimizing the range of stimuli films used. If the number of films can be reduced it would make synchronizing between participants more straightforward. To overcome the lack of synchronicity, we analysed the two minutes proceeding and after the first tear as the common feature between weepers. For non-weepers they did not have this behavioural marker, so the start of the sad scene was used. This may mean that time comparisons between weepers and non-weepers are not as controlled compared to standardised stimuli where there is greater temporal matching between groups. This reduction in experimental control is especially problematic for physiological measurements where there is already a large naturally occurring variance between participants (Stemmler & Fahrenberg, 1989). Therefore, it is most appropriate in situations where there is a behavioural response in which to synchronise across participants, in our case in was the production of the first tear. Despite this weakness, if there is similarity between participants across different films we can be more certain the physiological response is due to the behaviour and not a product of something else contained within the stimulus.

The current study was focused on the psychophysiology of weeping and classified participants by whether they shed a tear or not. Some participants in the weeping group had only one tear whilst others had a very intense and prolonged crying episode. This variation was also found in the non-weeping group. Some non-weepers showed no reaction to the sad film whilst others had heavily watered eyes although no tear was actually shed. We are also unsure of how many crying behaviours would be present during the suppression of tears. It is possible that watery eyes may be a feature present in episodes of crying and episodes of tear suppression. It is also likely that there is a level of suppression proceeding most episodes of weeping (Gross, 2013; Labott & Teleha, 1996). Overall, this variation in crying behaviour across both groups could account for the large variation in physiological responses which in turn leads to a high amount of statistical ‘error’. To account for this, a reliable measure of crying intensity and suppression intensity is much needed in the literature. Currently a basic categorical system based on a scale of behaviours from ‘felt like crying’ to ‘weeping and wailing’ is used but this distinction may not truly capture the full range of intensities present when people cry.

There is also difficulty in attributing causal relationships between weeping and subjective affect. Whilst weepers reported more sadness, we do not know whether they got sadder because of weeping or if they wept because of the intensity of emotion. There is some indication that emotional behaviour can increase underlying subjective affect (Bushman, 2002). From this perspective, the tear production leads to more intense feelings of sadness. However, there can be little doubt that weeping is a response to intense emotions, normally in the sadness family. Weeping is most prominent when the emotional event generates intense feelings of emotion. One way to disentangle this relationship is to look at the suppression of weeping. By using a response focused suppression technique (Gross, 1998), we can address whether the withholding of tears is linked to reduced feelings of sadness compared to weepers.

3.5.6 Conclusion

In conclusion, this chapter addressed whether intensity of the crying episode explained why when participants are asked to remember events that made them cry they often report crying improved but when crying is induced in the laboratory participants often rate themselves as feeling worse. Intensity of crying, specifically crying that includes weeping, is often confounded with the mode of study, laboratory induced crying is often mild and does not contain weeping. We found that as opposed to leading to physiological restoration, weeping was related to larger thermal changes and more negative affect over and above any crying behaviour that did not include weeping. This places weeping in line with the increased arousal hypothesis. Weeping was associated with large temperature increases in the face of a magnitude rarely seen in the literature. These temperature changes were strongly correlated to subjective affect which is very rare in emotion research, where there is a striking absence of subjective and physiological coherence (Mauss et al., 2005).

The thermal response was found in the absence of large changes in cardiorespiratory or electrodermal responses suggesting thermal imaging may be a more sensitive measure of emotion. Whilst previous studies have used the presence of any perceived crying behaviour, such as watery eyes, to categorised criers we used a more concrete objective distinction, a tear must become external to the eye. The thermal camera allowed us to see exactly when the tear is produced because of the thermal properties of the tear, making thermal imaging the best objective measure to detect the onset of weeping. Our study supports the increased arousal hypothesis which is best reflected in the subjective emotion ratings. The biggest difference between weepers and non-weepers was not in sadness but in relaxation. Weepers were less relaxed compared to non-weepers, or in other words more aroused. Both the thermal data and subjective ratings suggest weeping is a critical feature in the cluster of behaviours categorised as crying. Overall, weeping did not explain the paradox of crying and in fact weeping led to increased physiological arousal compared to non-weepers.

Chapter 4: Stemming the tide: The psychophysiology of tear suppression

4.1 Abstract

Adult emotional crying is linked to experiences of intense emotion; however, most human adults have a remarkable level of regulatory control over when and where they cry. People often report withholding tears when in a public setting until they are in a more private setting even though tear suppression is often considered to be detrimental to psychological well-being. Despite how common tear suppression is, it has received very little empirical focus. This chapter explores tear suppression from a psychophysiological viewpoint to assess whether withholding tears leads to increases or decreases in autonomic nervous system activity. Forty female ‘super-criers’ watched a film of their choice whilst we measured a range of physiological indices including facial temperatures, heart rate, skin conductance and respiration rates. Twenty of the participants were asked to suppress all emotional expressions. Episodes of successful tear suppression were characterised by physiological inactivity, whilst episodes of weeping were associated with large increases in facial temperatures, increases in heart rate and electrodermal activity whilst weepers had a larger reduction in respiration rates. We found no evidence that tear suppression had negative effects on physiology or that weeping relieved physiological stress. We suggest the withholding of tears may be appropriate in certain contexts and when someone chooses to withhold tear this is having no short term effects on their physiology.

4.2 Introduction

Adult crying is an emotional expression linked to the experience of (often) intense emotions; however, most adults show a remarkable level of regulatory control (Kraemer & Hastrup, 1988; Simons et al., 2013; Vingerhoets & Bylsma, 2016). One of the most reported phenomena when people are asked about their crying experiences is the ability to suppress crying until they are in a more suitable context. Most often this is observed when people refrain from crying in a public setting, such as at work, in favour of crying in a more private setting, such as at home (Vingerhoets, 2013). Given the strong lay beliefs about the possible detriments of withholding tears (Sharman et al., 2018), people still chose this approach rather than suffer the possible social stigma associated with producing tears in an inappropriate setting (MacArthur & Shields, 2015; Simons et al., 2013). Compared to the suppression of facial expressions, the suppression of tears has received very little empirical focus. In popular culture it is often claimed that having a good cry is cathartic and is a release of emotional tension (Sharman et al., 2018). However, there is evidence that the overt expression of emotion increases the intensity of the underlying affect (Bushman, 2002), therefore, suppressing tears might lead to reduced sadness and smaller physiological responses. This chapter looks to explore the physiological correlates of tear suppression and whether episodes of suppression are characterised by increased or decreased responding compared to producing tears. If suppression of tears is linked to increased physiological arousal, we should find elevated heart rate levels, increased facial temperatures and increased skin conductance.

Crying is a compelling emotional expression that includes both visual and auditory elements (Vingerhoets, 2013; Vingerhoets & Cornelius, 2011). The most recognisable crying behaviour is the visible shedding of tears from the lacrimal apparatus, referred to as weeping (Gračanin, Bylsma, & Vingerhoets, 2018; Vingerhoets & Cornelius, 2011). This is usually accompanied by other visual elements including facial expressions (Vingerhoets, Cornelius, Van Heck, & Becht, 2000). The auditory elements include rhythmic, spasmodic breathing classified as sobbing, and at its most extreme, crying includes loud and uncontrollable wailing

(Gračanin et al., 2014). New-born infants do not weep until around 4-6 weeks and so episodes of crying are primarily episodes of wailing (Vingerhoets & Cornelius, 2001). However, adult crying is almost entirely a visual signal with most episodes of crying characterised as silent weeping (Vingerhoets et al., 2000; Vingerhoets & Bylsma, 2016). Alongside the shift from acoustic to visual behaviours there is a shift in the antecedents of crying. In the absence of language, crying is the primary communication tool for children under one year of age and is used to communicate distress. This distress is a product of a range of physical and psychological states including hunger, tiredness, pain and loneliness (Gračanin, Bylsma, et al., 2018). Adults however rarely cry in times of physical distress, but cry during experiences of intense emotion (Vingerhoets et al., 2000).

Tears are potentially a powerful social signal that has a main function of eliciting help from others (Provine et al., 2009; Vingerhoets et al., 2016). Tears are associated with judgements of increased sadness and a can be considered a signal of helplessness and powerlessness (Balsters et al., 2013; Fridja, 1986; Provine et al., 2009). Weeping has been suggested to communicate an inability to cope and is often described as a sign of weakness (Simons et al., 2013; Vingerhoets et al., 2000). It is for this reason there are often large cultural and social pressures to inhibit weeping in public (Simons et al., 2013; van de Ven et al., 2017). This is most prominent in males who cry between four and seven times less frequently than females (Delp & Sackeim, 1987; Kraemer & Hastrup, 1988; MacArthur & Shields, 2015; Vingerhoets et al., 2000; Vingerhoets & Bylsma, 2016). Professional contexts, such as the workplace, are seen as places where weeping is not acceptable (Hoover-Dempsey et al., 1986); there are notable exceptions to this, for instance in a healthcare setting (Vingerhoets & Cornelius, 2001). The suppression of emotions is broadly categorised into two types. Antecedent focused regulation which involves the reappraisal of the emotional stimulus to down-regulate the emotion and lessen the intensity of the emotional experience (Gross, 1998). Whilst response focused regulation is categorised as the suppression of the emotional behaviour with little change to the subjective experience (Gross, 1998; Gross & Levenson, 1993, 1997). The inhibition of tears is clearly a type of response focused suppression.

Despite how commonly weeping is suppressed, there are relatively few empirical studies on the suppression of tears. Suppression of tears was linked to lower heart rates (Kraemer & Hastrup, 1988) and a reduction in both frequency of skin conductance fluctuations (Kraemer & Hastrup, 1988) and skin conductance level (Labott & Teleha, 1996). The relationship between suppression of tears and negative affect appears to be modulated by weeping propensity, with high frequency criers finding it more stressful to inhibit crying than low frequency criers (Labott & Teleha, 1996). One of the major difficulties in studying the suppression of tears is that it is extremely difficult to know whether a participant is actually suppressing emotional expression compared to the emotion not being intense enough to produce tears. Labott and Teleha (1996) used a split on crying intensity with participants who rated below ‘watery eyes’ classed as suppressing crying. There was no specific instruction to suppress emotional expressions and there was no measure of suppression. Kraemer and Hastrup (1988) experimentally split the group and gave instructions to suppress tears, however, they did not measure whether the participants in the suppression condition actually suppressed tears. It is therefore impossible to separate the participants who just did not cry because they were not sad enough and those who did not cry because they suppressed tears. This distinction highlights a wider issue with the laboratory study of weeping. The contextual situation created by the laboratory strongly influences the prevalence of weeping behaviour. It is neither private nor a familiar setting, both of which are indicated as important aspects as when and where people chose to cry (Bylsma et al., 2008; Vingerhoets et al., 2000). It is therefore extremely difficult to induce weeping in the laboratory; and when somebody does not weep, this may be a consequence of tear suppression or lack of emotional intensity required to produce weeping.

Response-focused suppression is usually associated with increased physiological responding over and above an unregulated emotional experience and is attributed to the additional cognitive effort required to self-monitor (Gross, 1998; Gross & Levenson, 1993; Labott & Teleha, 1996). This relationship explains why high frequency criers reported more stress than low frequency criers during suppression (Labott & Teleha, 1996). For high frequency criers it requires a lot of effort to suppress tears; this increased cognitive effort is reflected in increased stress. However, the cognitive effort explanation doesn't explain why there was a decreased physiological response for tear suppression compared to weeping (Kraemer & Hastrup, 1988). We would expect that any form of tear suppression is more cognitively taxing than not suppressing it, therefore, should be associated with increased levels of arousal. However, it may be the case that the physiological response is reduced *relative* to the large physiological response due to weeping (Ioannou et al., 2016).

To ensure that participants suppressed tears we recruited 'super-criers'. Super criers can be defined as high-frequency criers who find lots of situations bring them to tears. In tandem with recruiting people who cry a lot, to many situations, we used an idiographic induction technique so the participants chose their own film that induces weeping. This combination of recruiting 'super-criers' and asking them to choose a tear provoking stimulus film makes sure episodes of non-weeping are very likely to be because of suppression and not lack of intensity. Alongside, specifically recruiting super-criers our study will be the first to combine traditional cardiorespiratory and electrodermal measures with thermal imaging which has been shown to be excellent way to measure the ANS during episodes of weeping (Ioannou et al., 2016, also Chapter 3 of this thesis). The main aim of this research is to identify if there are any psychophysiological correlates of tear suppression and whether these are related to increased arousal over and above weeping. If weeping does have a cathartic function then episodes of tear suppression should be characterised by increased and prolonged physiological arousal, which we would expect to be particularly pronounced in super-criers.

4.3 Method

4.3.1 Ethics

Ethical approval was given by the Research Ethics Committee of the Faculty of Science, University of Portsmouth. The procedures were in line with the Declaration of Helsinki and the British Psychological Society code of human research ethics.

4.3.2 Participants

Forty females were recruited based on self-identifying as a super-crier. Participants were randomly split into two instruction groups. One group was asked to watch their chosen film with no particular instructions (n = 20, M_{age} = 20.75 years old, SD = 3.68) and one group was asked to suppress their emotional expressions while watching the sad film (n = 20, M_{age} = 22.55 years old, SD = 8.72). Participants were undergraduate students and participated for course credits.

A separate set of statistical tests were conducted to analyse the role of weeping. Despite instruction, 10 participants wept in the suppression condition. To analyse the role of weeping, both instruction groups were aggregated and then quasi-experimentally split depending on whether they wept during the sad film. This gave 27 weepers and 13 non-weepers.

4.3.3 Design

A mixed factorial design was used. The within subject factor was time, with response scores taken prior and during the sad scene of the film chosen by the participant. The between-subjects factor was whether the participant was asked to suppress their emotional expressions, with half of the participants asked to watch the film naturally whilst the remaining half were instructed not to show any emotional expressions. A variety of physiological variables were recorded including: Facial temperatures from six ROI (forehead, maxillary, nose-tip, cheek, chin, and periorbital), heart rate (HR), heart rate variability, measured using both the root mean of the squared successive differences (RMSSD) and respiratory sinus arrhythmia (RSA), skin conductance level (SCL), and respiration rates (RR). We also recorded the participant's subjective affect, crying intensity and suppression intensity.

4.3.4 Materials

Questionnaires. We used the Berkeley Expressivity Questionnaire (BEQ; Gross & John, 1995) to measure an individual's subjective assessment of their own emotional expressivity. Each item is answered using a 7-point Likert scale ranging from 1(strongly disagree) to 7 (strongly agree). The BEQ is separated into three separate factors: Negative Expressivity (6 items, score range 6-42), Positive Expressivity (4 items, score range 4-28), and Impulse Strength (6 items, score range 6-42). Scores were also combined to give a total expressivity score (16 items, score range 16-112). Higher scores indicated higher expressivity in that subscale.

Participants indicated their subjective levels of emotion. The instruction was: "Please indicate how much you feel the emotion currently" followed by a 10 point scale (1 low – 10 high). There were nine emotions: happy, sad, angry, boredom, interest, fear, amusement, disgust, and relaxation. The questionnaires were completed after the neutral and sad film.

Physiological data acquisition. Facial temperatures were captured using a FLIR A655sc (FLIR©) with an uncooled FPA microbolometer (640 x 480 LWIR resolution). The A655sc has a spectral range of 7.5 - 14µm, temperature sensitivity of <30 mK with and an accuracy ± 2% of reading. The videos were captured at a sampling rate of 25Hz/fps. The camera was controlled and data recorded using FLIR ResearchIR (FLIR©) software in a control room attached to the experimental room.

The electrocardiogram (ECG), skin conductance level (SCL) and respiration rates (RR), were captured using a BIOPAC™ MP160 system and Acq*Knowledge* 5 software from BIOPAC Systems Inc©. The ECG was connected to the participant using Ag/AgCl contact pad electrodes with a 11mm diameter (EL503 BIPOAC) in a 2 lead configuration. One lead was placed below the medial portion of the participant's right clavicle and the second lead was placed on the left side of the participant's thorax. The SCL was recorded from the distal phalanges of the middle and ring finger of the non-dominant hand using Ag/AgCl contact pad electrodes with a 11mm diameter (EL507 BIPOAC). A ground wire was placed on the back of the non-dominant hand. A respiration transducer belt (Bionomadix, TSD201 BIOPAC) was placed around the thorax to capture RR. All digital signals were sampled at 2000Hz with pre-programmed digital filters included with the BIOPAC amplifiers ECG100C for ECG, EDA100C for SCL and RSP100C for RR.

4.3.5 Stimulus materials.

An emotionally neutral film was used as a 'vanilla' baseline (Jennings et al., 1992). Participants watched the first seven minutes of a Ted Talk (Dawkins, 2005)[3]. This video was chosen to hold the attention of the participant whilst not inducing any emotion. The study used an idiographic approach to induce intense emotions. Participants were asked prior to attending the laboratory to select sad scenes from films or TV shows that had previous made them weep and would be likely to do so again. The choices were made entirely by the participant and obtained by the experimenter prior to their participation. Table 4.1 shows the films chosen by participants, how many wept whilst watching it and how many times that film was selected by participants in the suppression condition. Participants watched up to one hour of their chosen film starting approximately 40 minutes prior to the sad scene and continuing for about 20 minutes after, or until the end of the film, whichever was sooner.

[3] There is a possibility that some participants may have not liked Richard Dawkins, and this would have potentially induced an emotion. No participants reported this, but it is an important caveat none the less.

Table 4.1. Films and TV shows used during the experiment including number of participants that wept and number of times used in the suppression condition.

Film/TV show	Participants	Participants Wept	Suppress Condition
Marley and Me	8	5	6
Boy in the Striped PJs	6	3	4
Titanic	5	3	2
Notebook	4	3	0
Green Mile	3	3	2
The Impossible	2	2	1
Miss You Already	2	2	1
Lovely Bones	2	1	1
Beaches	1	1	1
Forest Gump	1	1	0
Outlander (S3 E05)	1	1	0
Grey's Anatomy (S11 E21)	1	1	0
Lion	1	1	0
Boys Don't Cry	1	0	1
My Sister's Keeper	1	0	1
A Walk to Remember	1	0	0

Note: Half the participants in the suppression condition wept.

4.3.6 Procedure.

The study was run in a sound attenuated psychophysiology laboratory consisting of an experimental room and adjoining control room. The participants were sat at a desk in the experimental room with a computer monitor approximately 0.75m away. A laptop was connected to the monitor to play the stimulus film. The infrared camera was behind the desk on a tripod approximately 1 meter from the participant positioned so there was an unobstructed view of the participants face. The BIOPAC amplifier was placed on the desk next to the computer monitor. The BIOPAC amplifier and thermal imaging camera were controlled by the experimenter from the adjoining control room.

Upon arrival participants completed the BEQ which took approximately 10 minutes, this allowed for the participant to acclimatise to the room temperature (Ioannou et al., 2014). They were then connected to the BIOPAC system and the ECG, SCL and RR signals were checked for signal clarity. The infrared camera and webcam were adjusted to the height of the participant. The participant then watched the neutral video and rated their subjective emotions. Finally, they watched their chosen sad film with the instructions to either “watch naturally” or “suppress their emotional expressions so that if somebody was watching them they would not know the emotional content of the film” (Gross, 1998). Participants watched their film for up to one hour and any tears were marked on the electrophysiology trace by the experimenter on the physiological system. Upon completion participants were disconnected from the system and indicated their subjective emotions for a final time.

4.3.7 Data extraction

Extraction of thermal data. The thermal data was analysed using FLIR Tools for PC (FLIR®). Average temperature was extracted from six ROI (Ioannou et al., 2014). Square shapes were used for the forehead and maxillary area, circular shapes for nose tip, periorbital and cheek, and an oval shape for the chin, figure 4.1). The size of the ROIs was kept stable throughout each video unless an obstruction, such as hair, changed the size of available surface. Picture frames were extracted every 60 seconds +/- 2 seconds. The best frame within the +/- 2 second tolerance was used to limit measurement noise and artefacts (Ioannou et al. 2014). Between participants, the size of the ROI changed depending on the morphology of the face although as a rule the ROI was as large as possible to give the most reliable average. One ROI was selected as an environmental invariant to continually adjust the thermal readings, this allowed us to account for unspecified thermal drift between camera calibrations.

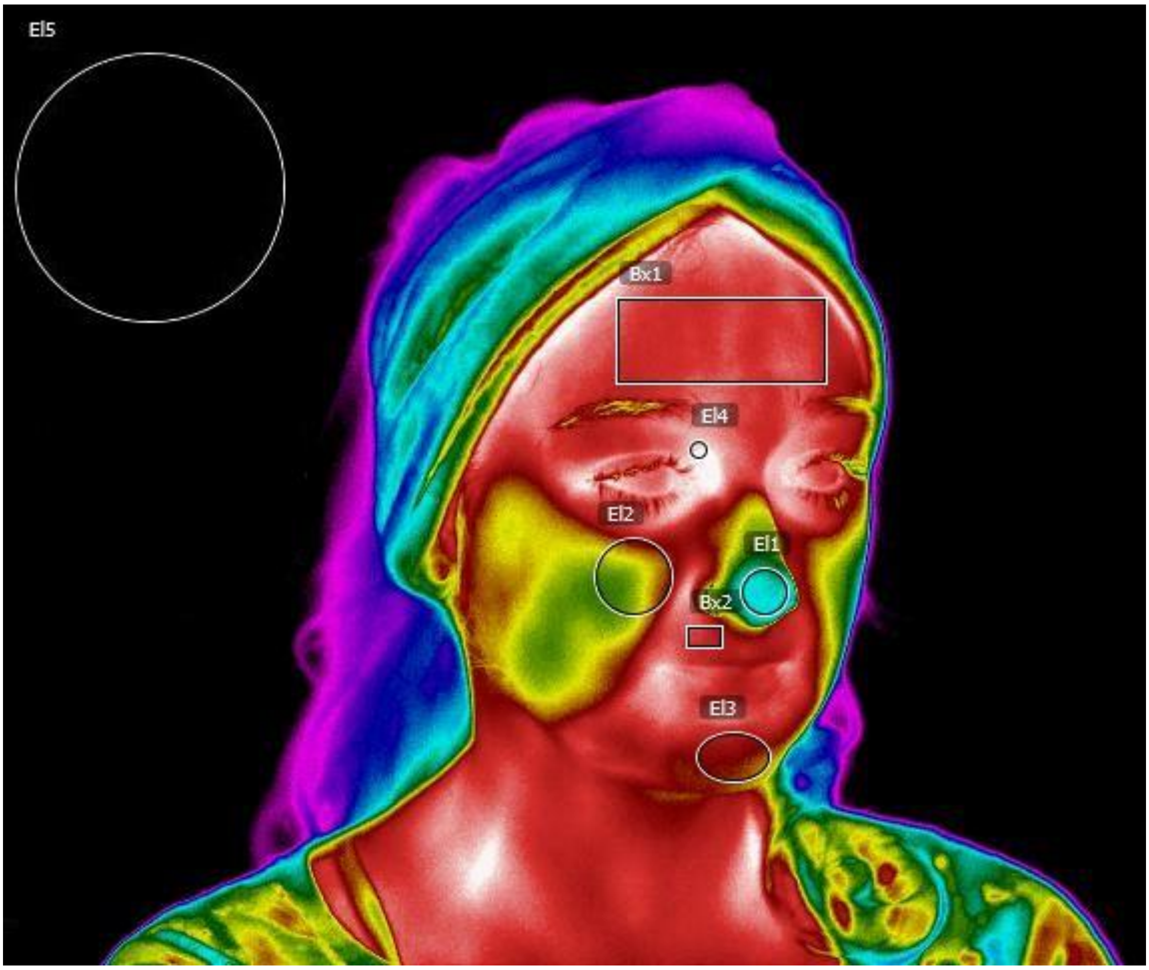

Figure 4.1. *Six ROI used to extract facial temperature (Bx1 forehead, Bx2 maxillary, El1 nose-tip, El2 cheek, El3 chin, and El4 periorbital) and one ROI for calibration (El5).*

Extraction of cardiorespiratory and electrodermal measurements. Data from the cardiorespiratory and electrodermal system were extracted using Acq*Knowledge* 5 software. The ECG, SCL and RR were down sampled to 500Hz, a 0.05 to 1Hz FIR band pass filter was applied to the transducer belt signal to improve clarity (BIOPAC Systems, n.d.). Acq*Knowledge* 5's automatic beat detection algorithm was then used to calculate HR and RR which were checked manually for artefacts. Statistical (RMSSD) and spectral HRV (RSA) was calculated using the software's inbuilt HRV modules. One minute epochs were created for condition and a mean score for HR, RR, SCL, RMSSD and RSA were then calculated for each time epoch.

4.4 Results

4.4.1 Confirmation there were no group differences during the neutral 'vanilla' baseline.

To check for group differences prior to experimentation *t*-tests were conducted on participant scores on the BEQ. There were no significant differences between participants in either instruction group. Table 4.2 shows the mean scores for each instruction group, the mean scores suggest both groups agreed with statements about being expressive and strongly agreed with statements in the impulsivity subscale which is focused on intensity of emotional behaviour including crying.

All participants watched a neutral video and were instructed to watch the video naturally. To test for differences between the two groups at baseline, subjective affect and physiological responses were compared. An independent group MANOVA comparing instruction groups was conducted with the nine ratings of subjective affect taken after watching the neutral video used as entered as dependent variables. There was no significant multivariate effect (p = .41, η^2_p = .26) and there were no significant differences between the watch naturally and suppress expression groups in any of the emotional ratings after watching the neutral video (Table 4.2). Participants in both groups rated themselves as moderately happy and interested with lower levels of boredom, relaxation and amusement. Participants rated themselves as feeling very little sadness.

Temperature change during the neutral video was calculated by taking the temperature in each region at one minute intervals and subtracting the temperature from that region in the first frame. To check for group differences in facial temperature whilst watching the neutral video a 2 (instruction group [watch naturally, suppress expressions]) x 6 (time [measurement taken every minute from 1 to 6minutes]) mixed factorial MANOVA was conducted on temperature change scores in each region of interest of the face. There was no significant multivariate effect of instruction group (p = .56, η^2_p = .14), no significant multivariate effect of time (p = .14, η^2_p = .91), and no significant multivariate interaction (p = .72, η^2_p = .77). Despite no significant effects, Table 4.2 shows that in the nose tip, maxillary and cheek temperature changes were larger than the 0.3ºC require to constitute a meaningful change (Ioannou, Gallese, et al., 2014). This mean temperature increase during the neutral video was found in both instruction groups.

Responses in cardiorespiratory and electrodermal systems was calculated by subtracting the mean score during the first minute from the mean scores from each of the subsequent minute during the five minutes of the neutral video. A 2 (instruction group [watch naturally, suppress expressions]) x 5 (time [measurement taken every minute from 1 to 6minutes]) mixed factorial MANOVA was conducted on changes scores from HR, RR, RMSSD, RSA and SCL. There was no significant multivariate effect of instruction group (p = .33, η^2_p = .17), no significant multivariate effect of time (p = .22, η^2_p = .68), and no significant multivariate interaction (p = .83, η^2_p = .47). Overall, there were no significant group differences in subjective affect or psychophysiology during the neutral video and both groups were comparable. This suggests there were no systematic differences between the suppression group or watch naturally group when watching the neutral film.

Table 4.2. Means and standard deviations of scores on the Berkley Expressivity Questionnaire, maximum change scores in psychophysiology as a function of whether the participant was asked to suppress emotional expression.

	Watch naturally		Suppress expression	
Measure	Mean	S.D.	Mean	S.D.
BEQ				
Negative	26.56	6.64	28.40	7.01
Positive	22.47	5.10	24.30	3.36
Impulse	33.72	6.54	36.05	4.84
Total	82.47	16.93	88.75	13.35
Subjective affect (1-10)				
Happiness	5.56	2.33	5.85	2.13
Sadness	1.72	.89	2.20	2.07
Anger	1.33	.49	1.50	1.40
Fear	1.67	1.46	1.65	1.69
Amusement	4.11	2.40	4.45	1.96
Disgust	1.00	0	1.4	1.79
Boredom	3.17	2.53	4.05	2.93
Interest	5.67	2.38	5.60	2.30
Relaxation	4.83	2.38	6.10	1.89
Facial temperature change*				
Forehead (°C)	.07	.24	.03	.16
Maxillary (°C)	1.31	1.24	.99	.70
Nose Tip (°C)	2.22	2.46	1.85	1.87
Cheek (°C)	.51	.42	.36	.35
Chin (°C)	.27	.50	.22	.31
Periorbital (°C)	.16	.29	.04	.15
Cardiorespiratory change*				
Heart rate (bpm)	1.41	3.39	1.61	4.55
Respiration rates (cpm)	.79	3.07	-.52	2.10
RMSSD (ms)	-5.29	12.75	-3.29	11.19
RSA (ms)	-.33	.69	-.20	.45
Electrodermal change*				
Skin conductance (µS)	1.47	2.75	.44	2.66

Note: * indicates largest change during the six minute neutral video.

4.4.2 Psychological factors of tear suppression.

Differences in intensity of weeping and suppression as a function of instruction group. Overall, 27 participants wept whilst watching the sad film, 17 in the watch naturally condition and 10 in the suppress expression condition. Participants rated on a ten point scale how intensely they wept and how intensely they withheld tears. An independent groups MANOVA, with instruction group as a between subjects' factor, was conducted on weeping and suppression intensity ratings. There was a significant multivariate effect of instruction group with a large effect size, $\lambda = .43$, $F(2, 34) = 22.50$, $p < .001$, $\eta^2_p = .57$. Univariate ANOVAs show that participants in the suppression instruction condition rated their weeping intensity as significantly lower ($M = 2.67$, $SD = 2.89$) than participants in the watch naturally condition ($M = 4.84$, $SD = 2.67$) with a small effect size ($p = .023$, $\eta^2_p = .14$). Participants in the suppression instruction group also rated their intensity of withholding tears as significantly higher ($M = 7.33$, $SD = 1.97$) than those in the watch naturally instruction group ($M = 2.58$, $SD = 2.69$) with a large effect size ($p < .001$, $\eta^2_p = .52$). Overall, participants in the suppress expression instruction group reported withholding their tears more and weeping less intensely.

Subjective affect in the suppression and weeping conditions. To compare the instruction groups subjective affect, an independent group MANOVA was conducted on the ratings from the nine emotional categories. There was no significant multivariate effect of instruction group ($p = .61$, $\eta^2_p = .20$). Figure 4.2 shows that the ratings of emotion in each of the instruction conditions were very similar. For both instruction groups participants rated themselves as sad and interested.

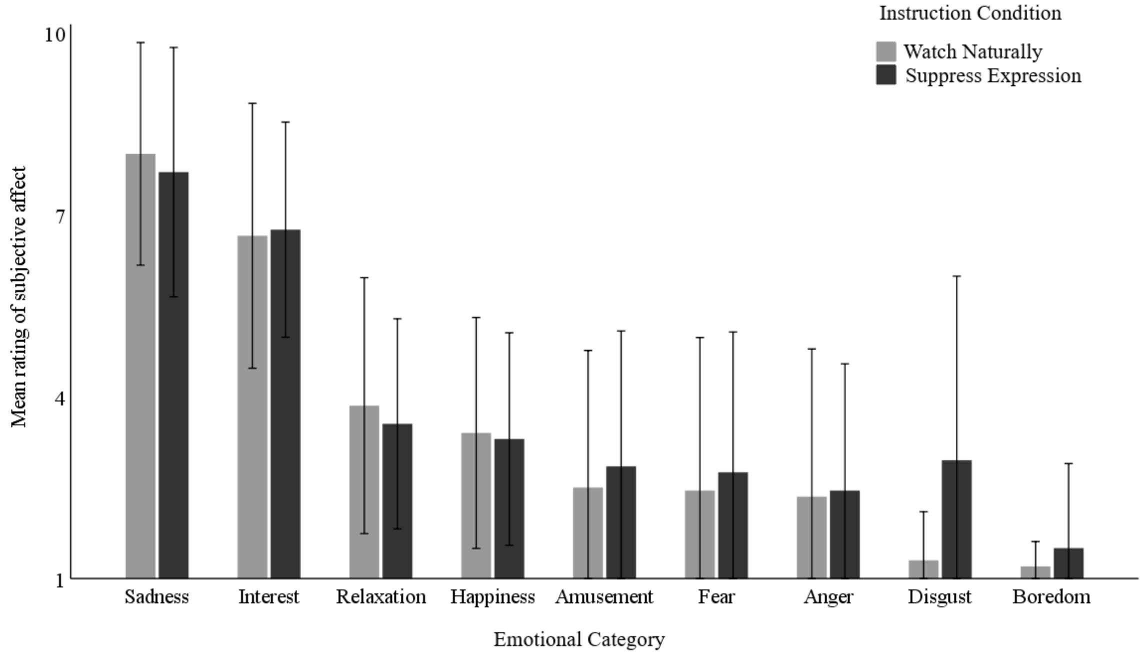

Figure 4.2. Mean ratings of affect as a function of instruction condition. Error bars represent 1 SD.

Scores from both instruction conditions were aggregated and the participants were split depending on whether they wept during the sad film. To analyse the role of weeping, an independent group MANOVA with a between subject factor of whether the participant wept was conducted on the ratings from the nine emotional categories. There was no significant multivariate effect of whether the participant wept (p =.69, η^2_p = .18). Figure 4.3 shows that rating of subjective affect did not vary depending on whether the participant wept and that both groups indicated that they were both sad and interested.

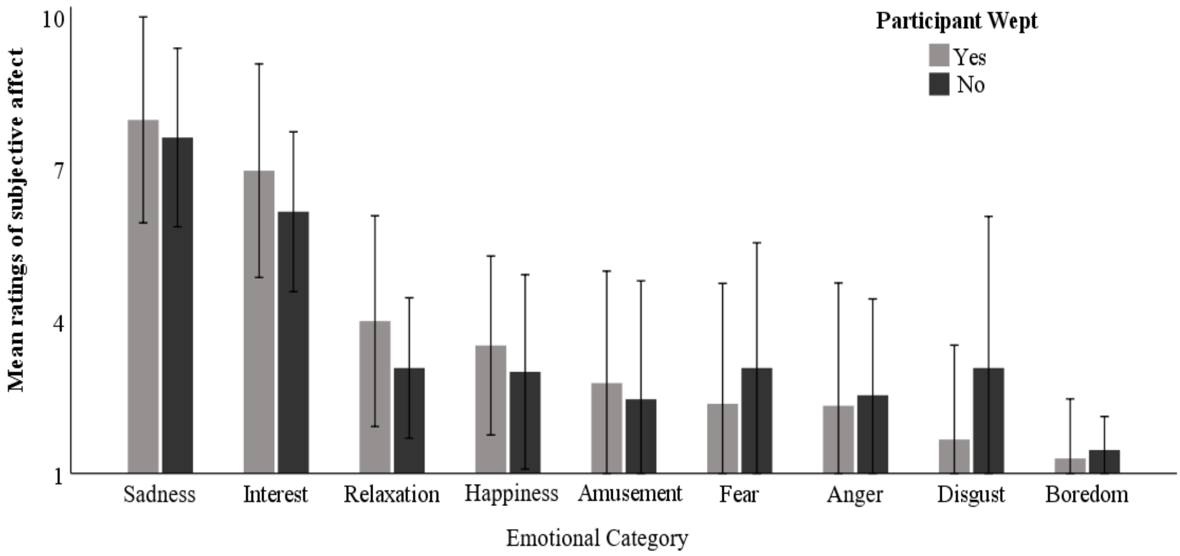

Figure 4.3. Ratings of subjective affect as a function of whether the participant wept. Error bars represent 1 SD.

4.4.3 Physiology and the suppression of tears.

To analyse the role of tear suppression on physiology, response scores were calculated for each physiological metric. For facial temperatures, measurements taken from the first frame of the thermal video were subtracted from the measurements of the subsequent frames. Whilst for cardiorespiratory and electrodermal measures, the mean during the first minute of the sad condition was subtracted from the mean of the subsequent minutes. A mean change score was then calculated for two five minute time phases. The pre-sad phase was the five minutes immediately preceding the sad scene of the film, whilst the sad phase was the first five minutes of the sad scene

Facial temperatures as a function of instruction group. A 2 within group factor (time) x 2 between group factor (instruction group [watch naturally, suppress expression]) mixed factorial MANOVA was conducted on the response scores from each of the six ROI entered as dependant variables (forehead, maxillary, nose tip, cheek, chin, periorbital). There was a significant multivariate main effect of time with a large effect size, $\lambda = .53$, $F(6, 33) = 4.89$, $p = .001$, $\eta^2_p = .47$. There was no significant multivariate main effect of instruction group ($p = .16$, $\eta^2_p = .23$) and no significant multivariate interaction ($p = .11$, $\eta^2_p = .26$). The significant multivariate main effect of time was explored using univariate ANOVAs for each of the region of interest. Table 4.3 shows for each region of interest there was a larger increase in temperature during the sad scene compared to the time preceding the sad phase, all with medium effect sizes.

Table 4.3. Univariate summary statistics for temperature changes as a function of time.

	Pre-Sad Phase		Sad Scene				
ROI	*M*	*SD*	*M*	*SD*	*r**	*p*	*d*ᵻ
Nose Tip	.74	1.83	2.53	2.94	.49	<.001	.72
Maxillary	.44	.72	.89	.98	.56	.001	.56
Cheek	.34	.52	.79	.82	.64	<.001	.77
Chin	-.05	.42	.23	.65	.68	<.001	.64
Forehead	.13	.23	.30	.33	.64	<.001	.70
Periorbital	.21	.22	.33	.31	.76	<.001	.64

Note: * Correlation between change scores, ᵻ calculated from pooled *SD*

Facial temperatures as a function of weeping. To explore the role of weeping a 2 within group factor (time) x 2 between group factor (Wept [wept, did not weep]) mixed factorial MANOVA was conducted on the response scores from each of the six ROI entered as dependant variables (forehead, maxillary, nose tip, cheek, chin, periorbital). There was a significant multivariate main effect of time, $\lambda = .66$, $F(6, 32) = 2.81$, $p = .026$, $\eta^2_p = .35$, a significant multivariate main effect of weeping, $\lambda = .60$, $F(6, 32) = 3.59$, $p = .008$, $\eta^2_p = .40$, and a significant interaction between weeping and time, $\lambda = .62$, $F(6, 32) = 3.27$, $p = .013$, $\eta^2_p = .38$, all with medium to large effect sizes.

To further explore the relationship, separate univariate ANOVAs were conducted on each of the ROIs independently. There was a significant main effect of time for all ROI (all p values <.05), temperature increases during the sad scene were larger compared to the temperature increases during the pre-sad phase. The univariate main effect of weeping showed participants who wept had significantly larger responses than non-weepers in the forehead ($p = .009$), maxillary ($p = .001$) and chin ($p < .001$). There was no significant difference between weepers and non-weepers in the nose, cheek, and chin. The main effects however should be interpreted in light of the significant interaction found in all regions of interest (all p values $< .05$). Table 4.4 shows that, in all ROI, participants who wept had a significantly larger increase in temperature during the sad scene compared to the pre-sad phase, whilst the non-weepers had a similar increase in temperature over both time phases. Overall, whether the participant wept was a bigger determinant of increased facial temperature than the suppression of tears.

Table 4.4. Temperature change scores in both time periods in °C as a function of whether the participant wept in each of the regions of interest.

	Pre-Sad Phase		Sad Scene		Summary Stats.		
ROI	*M*	*SD*	*M*	*SD*	*r**	*p*	*d* ᵻ
Nose tip							
Weeper	**.70**	**1.61**	**3.37**	**2.79**	**.32**	**<.001**	**1.00**
Non weeper	.66	2.26	.71	2.57	.91	.94	.05
Maxillary							
Weeper	**.30**	**.71**	**.98**	**1.06**	**.51**	**<.001**	**.79**
Non weeper	.67	.72	.68	.84	.91	.98	.03
Periorbital							
Weeper	**.22**	**.22**	**.42**	**.30**	**.73**	**<.001**	**1.04**
Non weeper	.17	.22	.13	.26	.96	.41	.58
Cheek							
Weeper	**.39**	**.57**	**.99**	**.81**	**.54**	**<.001**	**.89**
Non weeper	.21	.51	.32	.67	.93	.50	.49
Chin							
Weeper	**-.11**	**.45**	**.29**	**.73**	**.61**	**<.001**	**.75**
Non weeper	.05	.37	.09	.48	.89	.76	.20
Forehead							
Weeper	**.11**	**.23**	**.35**	**.35**	**.58**	**<.001**	**.88**
Non weeper	.16	.24	.19	.30	.95	.69	.39

Note: * Correlation between pre and post response scores, ᵻ calculated from pooled *SD.* Bold indicates a significant difference between time periods, all comparisons used a Bonferroni adjustment.

Cardiorespiratory and electrodermal activity as a function of instruction group. To explore the effect of tear suppression on cardiorespiratory and electrodermal responses, a 2 within group factor (time) x 2 between group factor (instruction group [watch naturally, suppress expression]) mixed factorial MANOVA was conducted on the response scores from HR, RR, RMSSD, RSA and SCL. There was a significant multivariate main effect of time with a large effect size, $\lambda = .60$, $F(5, 30) = 4.05$, $p = .006$, $\eta^2_p = .40$. There was no significant multivariate main effect of instruction group ($p = .23$, $\eta^2_p = .20$) and no significant multivariate interaction ($p = .21$, $\eta^2_p = .21$). The significant multivariate effect of time was further analysed by analysing the dependent variables separately. Table 4.5 shows during the sad scene HR and SCL were significantly higher and respiration rates were significantly lower than during the pre-sad phase.

Table 4.5. Means and standard deviation of the cardiorespiratory and electrodermal indices as a function of time period.

	Pre-Sad Phase		Sad Scene				
Measure	*M*	*SD*	*M*	*SD*	*r**	*p*	*d*ᵻ
Heart rate (bpm)	**2.22**	**4.06**	**4.12**	**5.74**	**.58**	**.02**	**.42**
Respiration rate (cpm)	**-.47**	**2.15**	**-1.43**	**2.90**	**.74**	**.01**	**.52**
Skin Conductance (µS)	**-.33**	**2.42**	**.41**	**2.11**	**.63**	**.03**	**.36**
RMSSD (ms)	1.40	7.66	3.25	13.93	.30	.39	.14
RSA (ms)	.17	.80	.52	1.37	.12	.18	.24

Note: * Correlation between pre and post response scores, ᵻ calculated from pooled *SD*. Bold indicates a significant difference between time periods, all comparisons used a Bonferroni adjustment.

Cardiorespiratory and electrodermal activity as a function of weeping.

To explore if weeping impacted the results, a 2 within group factor (time) x 2 between group factor (Wept [wept, did not weep]) mixed factorial MANOVA was conducted on the response scores from HR, RR, RMSSD, RSA and SCL. There was a significant multivariate main effect of time with a large effect size, $\lambda = .69$, F (5, 30) = 2.71, $p = .039$, $\eta^2_p = .31$. There was no significant multivariate main effect of whether the participant wept ($p = .26$, $\eta^2_p = .19$) and no significant multivariate interaction ($p = .06$, $\eta^2_p = .28$). The multivariate main effect of time was further explored by looking at the dependent measures separately. There was a significantly bigger drop in respiration rates during the sad scene ($M = -1.53$, $SD = 2.88$) than during the pre-sad phase ($M = -0.54$, $SD = 2.13$) with a small effect size ($p = .017$, $\eta^2_p = .16$). There was no significant difference between time periods for heart rate ($p = .2$, $\eta^2_p = .05$) , skin conductance ($p = .08$, $\eta^2_p = .09$), RMSSD ($p = .40$, $\eta^2_p = .02$), and RSA ($p = .07$, $\eta^2_p = .07$). The multivariate interaction approached significance and to allow for a comparison with thermal responses these were further analysed. For weepers only, there was significant differences in HR, SCL and RR between the two time phases with medium to large effect sizes. There was significantly larger HR increase during the sad scene compared to the smaller HR increase during the pre-sad phase. SCL declined from baseline during the pre-sad phase whilst there was a significant increase in SCL during the sad scene, and there was a significantly larger reduction in RR during the sad scene than the reduction during the pre-sad phase. There were no significant differences between the two time periods for either RMSSD or RSA. There were no significant differences between the two time periods for non-weepers although RSA approached significance (see table 4.6)

Table 4.6. Response scores in both time periods as a function of whether the participant wept.

Cardiorespiratory and electrodermal measures	Pre-Sad Phase		Sad Scene				
	M	*SD*	*M*	*SD*	*r**	*p*	*d* ɪ
Heart Rate (bpm)							
Weeper	**2.30**	**4.45**	**5.68**	**5.59**	**.67**	**<.001**	**.82**
Non weeper	2.06	3.17	.58	4.52	.44	.252	.36
Respiration Rate (cpm)							
Weeper	**-.55**	**2.35**	**-1.61**	**3.18**	**.74**	**.012**	**.53**
Non weeper	-.28	1.67	-1.01	2.22	.25	.233	.30
Skin Conductance (μS)							
Weeper	**-.10**	**2.39**	**.80**	**2.13**	**.59**	**.023**	**.44**
Non weeper	-.87	1.79	-.48	1.86	.69	.497	.27
RMSSD (ms)							
Weeper	1.29	8.08	2.90	15.95	.24	.553	.11
Non weeper	1.66	6.97	4.05	8.23	.70	.560	.41
RSA (ms)							
Weeper	.24	.91	.36	1.02	.21	.680	.10
Non weeper	-.01	.44	.88	1.96	-.18	.051	.41

Note: * Correlation between pre and post response scores, ɪ calculated from pooled *SD*. Bold indicates a significant difference between time periods, all comparisons used a Bonferroni adjustment.

In summary, weepers showed larger increases in HR and GSR from baseline during the sad scene compared to the five minutes preceding the sad scene. Weepers also had a larger decrease in RR during the sad scene compared to the five minutes prior to the sad scene. Successful suppressors had no significant differences in HR, GSR or RR between the two time phases. HRV responses remained similar in both time phases, for both weepers and successful suppressors.

4.4.4 Coherence between subjective affect and physiology

The participants ratings of subjective affect were correlated with the mean physiological response score taken during weeping or suppression. The alpha level was adjusted using a Bonferroni correction for multiple tests (99 tests, $\alpha = .0005$). After correction none of the physiological measures correlated with the subjective affect. Table 4.7 shows that for the most intensely felt emotion only cheek temperatures ($R^2 = .07$) and skin conductance level ($R^2 = .07$) showed even a small effect size in relation to sadness scores.

Table 4.7. Pearson's correlation coefficients between subjective affect and physiology

	Sad.	Interest	Relax.	Happ.	Amus.	Fear	Anger	Disgust	Bored.
Temperature									
Forehead	.08	.05	.06	-.08	.03	.06	.17	.40	.38
Maxillary	.12	.19	-.02	.07	.25	.23	.24	.20	-.01
Nose Tip	.12	.07	-.08	-.04	.22	.16	.30	.30	.10
Cheek	.27	.19	.08	.10	.34	.02	.25	.28	.10
Chin	.11	.24	.05	.03	.09	.12	.10	.28	.12
Periorbital	-.07	.22	.15	.14	.06	.02	-.001	.16	.03
Cardioresp.									
Heart Rate	.19	.07	-.06	-.23	-.07	.12	.16	.38	.20
Respiration	.04	-.12	-.03	-.14	-.19	.04	.03	.03	.16
RMSSD	.01	-.20	-.11	-.08	-.04	-.29	-.15	-.21	-.20
RSA	.07	-.09	-.11	.10	-.01	-.01	.07	-.12	-.15
Electrodermal									
SCL	-.27	.25	.23	.24	.28	-.14	-.09	-.04	-.09

Note: A Bonferroni correction was used to adjust for multiple correlations. After correction, no correlations were significant.

4.5 Discussion

This study demonstrated that a participant's physiological response was related to whether the participant wept and not whether they suppressed emotional expressions. This pattern was found in facial temperatures, HR, RR and GSA. Whilst weeping led to considerable changes in physiological responding, the suppression of expression was characterised by similarity in physiological responses over both the pre-sad phase and the sad scene. This was especially noticeable in facial temperatures which showed large increases during the sad scene in weepers, whilst those who successfully supressed weeping did not show an increase in face temperature during the sad scene compared to the pre-sad phase. Subjective affect was very similar regardless of whether the participant supressed emotion or wept, suggesting it was not the underlying emotion that was driving the differences but, rather, weeping. This study highlights how suppression of tears did not increase physiological arousal, and compared to weepers, successful suppressers had lower physiological reactivity scores. When we interpret the physiological reactivity in light of there being no differences in subjective affect, it suggests there is a direct relationship between weeping and physiological responses regardless of the intensity of the underlying emotion. This is especially prominent for the large facial temperature increases which are found consistently in relation to weeping.

4.5.1 Facial Temperature responses during tear suppression and weeping

The changes in facial temperature were calculated for two phases of the sad film: five minutes during the sad scene and the five minutes preceding this. Compared to the five minutes leading up to the sad scene, there were larger facial temperature increases whilst the participants were viewing the sad scene. Further analysis showed that these changes were being driven by the weepers. Non-weepers had similar face temperatures during the sad scene as they did in the five minutes leading up to it. Non-weepers face temperatures remained stable during the ten minutes analysed regardless of whether the film content was sad or not. This is contrary to the weepers who showed an extremely large increase in temperature during the sad scene in all ROI.

Participants who successfully suppressed tears had no significant differences in facial temperature responses between the sad scene and the pre-sad phase, although the temperature was higher in these two phases compared to the baseline measurement. There are two possible explanations for this, the first and most obvious is that suppression of tears is not linked to facial temperature increases above the temperature change associated with watching a film. The second is that participants were suppressing tears during the pre-sad phase. The two time periods would both be periods of tear suppression and this would be reflected in similar scores during both time phases. What is difficult to measure is exactly when a participant is suppressing tears. Whilst the events in the stimuli films gives us a guide as to when sad events are happening, it is an imprecise metric. However, what is clear from the data is that the largest temperature increases are a product of weeping and not suppression.

4.5.2 Cardiorespiratory and electrodermal responses to tear suppression and weeping

Whether the participants were in the watch naturally or suppress expression group had no effect on cardiorespiratory and electrodermal systems. The two time periods did differ however, with a decrease in RR and increases in HR and SCL during the sad scene compared to the pre-sad phase. Further analysis showed these responses were associated with the weepers only. Successful suppression was associated with stability of HR, RMSSD, RSA, RR, and SCL whilst weepers had an increased physiological response. Weeping during the sad scene was associated with increased sympathetic nervous system activity (SNS), there was a large increase in HR and moderate increase in SCL. This increase in SNS activity was absent in the participants who successfully suppressed tears. There was also a reduction in RR for weepers due to sobbing which suggests increased parasympathetic nervous system (PNS) activity (Gračanin et al., 2014; Rottenberg et al., 2003). Heart variability did not differ over time or due to weeping status suggesting that the PNS wasn't affected by either suppression or weeping during the sad film. Overall, it was whether the participants wept that dictated physiological response and not whether they were asked to suppress their expressions.

Our data are consistent with the theory that the suppression of tears reduces physiological arousal (Kraemer & Hastrup, 1988; Labott & Teleha, 1996). Our data also suggests that the absence of SNS activity is key to that relationship. Weeping is preceded by a burst of SNS activity increasing HR and SCL which was absent in participants who successfully suppressed tears. What we did not find was the increased arousal due to emotional regulation that has been consistently found in the literature (e.g. Gross, 1998; Gross & Levenson, 1993). The reason why our data are not consistent with previous research finding may be due to the mildness of emotion inductions in previous studies. We believe the induction procedure used in this study produces relatively strong emotions and that cognitive mediation adds very little to an already elevated physiological system. Whereas, if the emotion is mild the cognitive mediation increases physiology *relative* to minimal change due to mild emotions.

4.5.3 Subjective affect and emotional coherence.

Overall participants rated themselves as very sad and interested. The ratings of subjective affect were not affected by instruction condition or whether the participant wept. Therefore, there is a fractionation between physiology and affect, with weepers having elevated physiological responses compared to suppressors but having similar levels of subjective affect. This is further highlighted by the lack of significant correlations between physiology and subjective affect[4]. It is, however, a major factor in response focused suppression that the underlying affect is not reduced but only the outward expression of emotion. The fractionation is not a new finding, with a separation between psychological and physiological components of emotion being a common finding in the literature regardless of any suppression (Mauss et al., 2005). The relationship between physiology and emotion is central to the key debate in the emotion literature regarding what emotions are (Siegel et al., 2018). The lack of correlations between physiology and subjective affect plays a major role in the arguments against ‘basic’ emotions and is often cited by constructionist theorists as a critical factor in why there is no physiological fingerprint for emotions, and therefore no causal biological neuro-circuitry (Averill, 1983; Barrett, 2006; Quigley & Barrett, 2014; Siegel et al., 2018).

4.5.4 Methodological considerations

The biggest methodological consideration for this study is the difficulty in identifying moments of suppression. Whilst we can be sure participants were suppressing tears, what is more difficult to identify is moment to moment differences in the intensity of suppression. We used the emotional content of the movie to guide our analysis but what is not certain is how physiology was affected during moments of intense suppression. What is difficult to assess is whether participants were suppressing continuously or whether there were short bursts of suppression interwoven with periods of strong emotion without the need to suppress tears. In

[4] A Bonferroni correction was used in this chapter whilst in Chapter 3 it was decided not to use a correction. Whilst it is generally inappropriate to use a Bonferroni correction for large numbers of correlations due to missing true positives, Chapter 4 also had much smaller effect sizes than Chapter 3. Therefore, even without a correction in Chapter 4 the majority of the correlations would have remained non-significant.

future studies it would be important to develop a method by which participants could indicate when they are suppressing tears. One possibility would be to have the participants watch the recording of themselves during the experiment and select moments of tear suppression.

Another potential issue with studying tear suppression in a laboratory environment is the potential effects the setting has on weeping in general. Laboratory settings are not a natural place to shed tears and they share common properties with settings associated with tear suppression. Laboratories contain strangers in the form of experimenters, lack social support and could be considered a public space as opposed to a private space. We tried to account for some of these issues by recruiting super-criers who seem to be less affected by these factors; however, it is possible that there was some emotional suppression in the watch naturally condition (Vingerhoets, 2013; Vingerhoets & Cornelius, 2001). It is therefore possible that the time period preceding episodes of weeping included emotional suppression. Any physiological response to suppression at these points would be masked by the physiological response during weeping. Again, the simplest way to assess this would be to develop methods for the participant to highlight or indicate when they are suppressing tears.

The fact that we received a high level of weeping in the suppress expression group was unexpected. A common issue in the crying literature is that inducing weeping is notoriously difficult due to the natural inhibition of crying in a public setting. However, when given explicit instructions to suppress expressions we expected this qualifying of a natural behaviour to have strengthened the suppression. This was not the case with 50% of the supress expression group still weeping. We believe that the idiographic induction technique coupled with recruiting 'super-criers' is the reason we found it difficult to stop people from weeping. This does also allow us to be confident that the times at which participants were not weeping during the sad scenes were highly likely to contain suppression. This is reflected in the subjective data with participants in the expression condition rating their intensity of suppression very highly. It also may be the case that ratings of suppression were impacted by demand effects of the experiment; the ratings represent a want to conform to the experimenter's request more than an accurate reflection off suppression intensity. While it is likely that demand effects play a role in the ratings, it was clear that there was more intense suppression in the suppression condition compared to the watch naturally condition. One of the next stages in understanding the suppression of tears will be to look at the same participants' physiology whilst watching sad films in both a suppression condition *and* a watch naturally condition. This will allow us to make direct comparisons during certain scenes both when the suppression was successful and when it was not.

Using an idiographic approach to inducing emotion we sacrifice temporal control for more intense emotions, and this may have been a factor as to why the suppression of tears had such a little effect of physiological responses. The intensity of the emotion caused elevated physiological responses regardless of instruction condition and was only surpassed by the large sympathetic response associated with weeping. Going forward, it seems important to develop a way to identify onsets and offsets of emotional experiences and emotional suppression without impacting on the participants experience whilst watching the film. The obvious way to do this would be to have participants indicate their level of suppression continuously throughout the film, although, this adds a level of cognitive reflection which may distract the participants or become a causal factor of suppression itself.

4.5.5 Conclusion

This study has shown that the successful suppression of tears was characterised by no physiological responses in both the pre-sad and sad time phases. However, weeping was also associated with large temperature increases, elevated HR, higher GSA, and lower RR during the sad scene compared to the pre-sad phase. This suggests that suppression of weeping prevents the large physiological response at tear production. The physiological data suggests weeping is associated with increased SNS activity at the time of tear production that is then reflected in the different autonomic measures. The suppression of tears may reflect the ability to keep calm and not succumb to SNS arousal. The physiological response to weeping was not reflected in psychological differences, subjective affect was similar in both groups. This suggests the physiological response is tied to weeping and not underlying negative affect. Our results are not consistent with much of the literature on the suppression of emotional expressions which suggested we might find increased arousal due to the cognitive effort it requires to suppress an emotion expression (Gross, 1998; Gross & Levenson, 1997). The largest physiological responses were found for participants who wept compared to participants who successfully suppressed tears, indicating that weeping does not seem to be restoring physiological homeostasis but is actually associated with increased activity in the SNS. This is important from a clinical perspective where tear suppression is viewed as problematic (Knox et al., 2017), and certainly from a physiological perspective this does not seem to be the case.

Chapter 5: Crying in context: How emotional context modulates perception of tears

5.1 Abstract

Adult weeping is a compelling social signal which generally elicits support from observers. The empirical evidence suggests weepers look sadder than non-weepers; furthermore, the addition of tears to a face increases attribution of sadness regardless of the facial expression. Given that weeping can be associated with a range of emotions, including joy and anger, it is interesting that weeping seems to directly affect ratings of sadness. One reason we may find the link between sadness and weeping is due to the lack of emotional context used in research. To address whether the addition of emotional context to videos of weepers affects the perception of tears, we created a database of 26 videos of people watching sad films, half included episodes of weeping. Multi-level modelling was used to analyse the ratings of 167 judges who attributed emotions to the film viewers in sad, joy, anger and fear contexts; modified by showing the judges a clip of a film the viewer was supposedly watching. Overall, weeping was related to increases in sadness in all contexts. Emotional context acted as a top down influence, changing the weepers' perceived emotions for some but not all of the judges. In this sense weeping was viewed as not only a pure signal for sadness but as being embedded in an emotional context.

5.2 Introduction

Emotional weeping (herein referred to as weeping) is the shedding of tears from the lacrimal apparatus. It is considered the primary feature of emotional crying (Gračanin, Bylsma, et al., 2018) and is often accompanied by other behaviours such as sobbing, facial expressions and vocalisations (Vingerhoets et al., 2000; Vingerhoets & Bylsma, 2016; Vingerhoets & Cornelius, 2001). Whilst many mammals produce tears to protect the eyes from physical irritants, humans seem to be the only animal that weeps due to emotions. Weeping appears in infants between 4-6 weeks of age and during infant development the acoustic elements of crying diminish whilst weeping becomes more pronounced (Provine, 2012; Vingerhoets & Bylsma, 2016; Vingerhoets & Cornelius, 2001). The benefit of weeping over wailing is that visual elements can be directed at people, although this may not be an intentional act, and in this sense is an observer-specific signal. Despite the move from a primarily acoustic signal to a primarily visual signal the function is similar. Weeping is used to gather support from others to aid in the removal of a source of discomfort, whether it be physical or psychological distress (Balsters et al., 2013; Hendriks, Croon, et al., 2008; Provine, 2012; Provine et al., 2009).

People report weeping because of many different emotions such as sadness, joy, anger and fear (Vingerhoets & Cornelius, 2001). Despite this, tears seem to convey a signal of sadness to the observer (Vingerhoets et al., 2016). This is potentially explained by the methodological limitations of previous research into the perception of tears. The standard paradigm is to use static images of the head and shoulders of someone expressing an emotion and digitally add or remove tears. These static images have often been cropped so that only the face is visible (Balsters et al., 2013) or in other studies it is only the eyes that are visible (Küster, 2018). Dynamic stimuli have been shown to be a more appropriate way to study facial expressions because they are intrinsically about decoding muscle contractions and the subsequent movement of facial features (Ambadar et al., 2005). By using static stimuli we remove the temporal characteristics of the display and subsequently remove the change in facial feature configuration that is critical to decoding emotional expressions (Ambadar et al., 2005). Given that the process of weeping involves movement, tears falling down the face, it seems important that there is an increased focus on the use of videos to study weeping.

The current literature on the social impact of weeping rarely presents any contextual information to participants (referred to in this paper as judges[5]) who make judgements on the emotions of others (Balsters et al., 2013; Hendriks & Vingerhoets, 2006; Provine et al., 2009). The only study to introduce emotional context, by adding background music associated with different types of emotion, found small contextual effects in the perception of weeping (Hanser et al., 2015). Pauw, Sauter, van Kleef and Fischer (2019) examined the effect of non-emotional contextual information by adding the reason for crying and found this had an effect on the level of support offered by judges, but had no effect on the attribution of emotions. The gender of the person crying has been found to have a large effect on perception; crying males are rated as highly emotional whereas crying females are rated as more incompetent (Fischer et al., 2013; Hendriks, Croon, et al., 2008). Only two studies have used dynamic film stimuli (Pauw et al., 2019; Reed et al., 2015) of which only Pauw et al. (2019) contained actual weeping targets. It is more common for researchers to use eye drops to create the illusion of weeping (Reed et al., 2015). Therefore, the literature is seriously lacking in ratings of *actual* weeping. Alongside the move to dynamic stimuli it is critical that these stimuli are of weepers really weeping.

Tears on the face share a communicative platform with other emotional expressions. The presence of tears on a static image of a face, whether the tears are real or digitally added, increases observers attributions of sadness and increases the willingness for observers to offer social support to the weeper (Balsters et al., 2013; Hanser et al., 2015; Hendriks, Croon, et al., 2008; Hendriks & Vingerhoets, 2006; Küster, 2018; Provine et al., 2009; Vingerhoets et al., 2016). The effect was also

[5] The use of this nomenclature, judges and targets, allows us to clearly define who is observing and rating who. Judges refer to observers and targets are those being observed.

obtained using stimuli presented for just 50ms suggesting a preconscious or automatic association between sadness and tears. This is regardless of the emotional expression being displayed (Ito et al., 2019; Reed et al., 2015). The opposite is also found when tears are digitally removed, ratings of sadness and willingness to help decrease (Provine et al., 2009). Given that tears are reported as being associated with a range of emotions such as joy, fear and anger (Reed et al., 2015; Vingerhoets & Cornelius, 2001), why do tears seem to be a clear and automatic signal of sadness?

The relationship between facial expressions and function has been a hotly debated issue in the emotion literature. The theory that facial expressions are direct emotional readouts (e.g. Buck, 1994) is strongly criticised by proponents of constructionist models of emotion who consider facial expressions as a socially flexible signal. They argue facial expressions do not exist in a social vacuum and as such, the use of facial expressions and their subsequent 'decoding' by perceivers is a social phenomenon. They stress that emotional expressions are situationally based and should be understood not by the expresser's underlying emotions but by the expresser's underlying social motivations (Crivelli & Fridlund, 2018; Fridlund, 2014). For this reason, the context of the target, the target's body language, the expresser's goals and the judges' experience all play critical roles in the interchange of affective information (for a review see Fernández-Dols & Russell, 2017).

There is mounting evidence that the emotional context is a key factor in decoding facial expressions (Calbi et al., 2017; Crivelli & Fridlund, 2018; Gendron et al., 2013). Furthermore, faces displaying no emotional expressions e.g., a neutral expression, placed in an emotional context are perceived as displaying an emotion congruent with the given context. This is referred to as the 'Kuleshov' effect after Soviet film maker Lev Kuleshov (Barratt et al., 2016; Calbi et al., 2017; Mobbs et al., 2006). Whilst the Kuleshov method is normally used to make a neutral face seem emotional, a similar method can change the way typical emotion expressions are perceived. For instance, a typical disgust face presented on body postures displaying anger, fear or neutral body language results in context driven emotional attributions by judges (Aviezer et al., 2008). The relationship between emotional context and perceived emotions seems to be mediated by the ambiguity of the expression. The more ambiguous the expression, the more dominant the contextual effect is (Mobbs et al., 2006). What is less clear is how large of an effect context will have on a behaviour, such as weeping, that appears to have a clear and robust effect on emotional attributions.

Given how important context is in the perception of emotional expressions, there has been remarkably little research on the effect of emotional context and weeping. The fact that weeping communicates sadness despite a range of emotions being possible elicitors of weeping, may be a product of the lack of emotional context provided in previous studies. Furthermore, despite weeping being the behaviour of interest, surprisingly few papers have used actual occurrences of weeping as the stimuli. Therefore, the aim of this study is to explore how episodes of actual weeping are perceived in a range of different emotional contexts. Context will be introduced by manipulating the film judges think that targets are watching. We used dynamic target videos of people actually weeping whilst watching a sad film. Judges rated the emotions of the targets and we used multi-level mixed effects modelling to answer whether emotional context affects judges' attributions of emotion and whether this effect is consistent across judges. Half of the target videos included episodes of weeping, so we explored whether the presence of tears changed emotional attributions and whether these changes were affected by the judge. Finally, we addressed whether the combination of weeping and emotional context modified the judge's attributions.

5.3 Method

5.3.1 Design

Twenty six target videos were created for the purpose of this study. Each video was of a target watching a sad film, thirteen target videos contained episodes of weeping (taken from the weepers in chapter 3). Judges rated six of the target videos randomly selected from the group of 26. Each target video rated by the judges was randomly presented in one of four emotional contexts, either happiness, sadness, anger or fear. The dependent variables were the level of intensity of nine emotional attributions made by the judges for each target: happiness, sadness, fear, anger, disgust, amusement, boredom, interest and relaxation. Therefore, a 2 (target wept vs. not wept) x 4 (emotional context: sadness, joy, fear, anger) multi-level mixed effect design was used. To create a no-context reference group (necessary for comparisons in mixed effect modelling), nine judges rated all 26 target videos without any context. Emotional context, whether the target wept and the interaction between these variables were treated as fixed effects whilst a random effect of both judge and target weeping were explored.

5.3.2 Participants

There were 166 judges all aged between 18 and 54 years old (M_{age} = 21.22 years, *SD* = 7.22). The majority were female (*n* = 137) and the majority were first year psychology students who received course credits for participation (*n* = 140). Nine of the judges rated all target videos without an emotional context, whilst the remaining 157 judges rated up to eight target video-context pairings[6] (*M* = 5, *SD* = 1.25).

[6] Originally participants were asked to complete eight pairings, however, we found that participants dropped out after making six judgements. We then shortened the experiment to six pairings and got a much better, although not perfect, completion rate.

5.3.3 Materials

Stimulus materials. The stimuli were comprised of two parts, a contextual video and a target video. There were eight contextual videos, two for each of the emotional contexts of sadness, joy, anger and fear. These contextual videos were roughly two-minutes long and taken from films. The chosen scenes were at the climax of the films' emotional event. Table 2.1 details the films, scenes and the descriptions given to judges. There were 26 target videos. All the targets were female and thirteen featured weeping of varying intensities. The videos were filmed using a high definition webcam whilst the females watched a film they chose to induce weeping.

Rating Scales. Each target video was followed by a ten-point rating scale (1 low to 10 high) for nine emotions in the following order; happiness, sadness, fear, anger, disgust, boredom, interest, relaxation and amusement. Happiness, sadness, fear, anger, disgust and amusement are considered primary emotions whilst boredom, interest are considered 'epistemic' emotions (Arango-Muñoz & Michaelian, 2014), finally relaxation acts as the inverse to arousal and is included with the epistemic emotions to separate it from the basic emotions.

5.3.4 Procedure.

Judges completed the study online using Qualtrics. Firstly, participants watched one of the eight context videos chosen at random, followed by the statement "the following person also watched this film", followed by random target video. Judges were then asked to rate the emotions of the target. Judges watched six randomised combinations of context video and target video but did not see the same context video or target video more than once. Overall, there were 208 possible context-target pairings and each possible pairing was rated at least once (M = 8.25, SD = 1.25). The number of judgements made for each target-context pairing can be found in the supplementary materials (Table 5.1). Nine independent judges rated all the 26 target videos with no context to create a reference group. Separate judges were chosen for this element to avoid any contextual influences that may have occurred if a non-context condition was included with the contextualised judgements.

Table 5.1. Description of the eight films used to provide emotional context.

Context and Films	Description
Sad	
Marley and Me	Marley, a golden retriever, is put to sleep because of illness. John Grogan says his goodbyes to his best friend
The Notebook	Allie who suffers from dementia expresses her fears to her true love Noah.
Joy	
Lord of the Rings: Return of the King	After a long a painful journey involving the death of friends and allies, the hobbit Frodo managed to destroy the 'one' ring and save Middle Earth. The scene depicts the reunion between Aragorn and Arwen and everyone paying respect to the four hobbits who saved Middle Earth.
The Impossible	Inspired by true events of a family on holiday in Thailand during the 2004 Tsunami. Harry Bennet searches for his family in the aftermath of the Tsunami. The family reunited at a local hospital.
Anger	
My Bodyguard	After Ricky helps his younger friend stand up to a bully, the bully enlists the help of a bodyguard to physically intimidate and bully Ricky. The scene depicts the intimidation and bullying of Ricky.
Cry Freedom	During the South African apartheid regime of racial segregation, white Afrikaan soldiers open fire upon a protest.
Fear	
Alien	Ripley is the only survivor of a brutal alien attack that killed her entire crew. She has escaped in a small jump ship leaving the alien to die along with her space station. Unknown to her the alien has also boarded the jump ship.
Verónica	Verónica and her friends play with a Ouija board during a solar eclipse.

5.3.5 Data analytical strategy

Data were analysed using MLwiN 3.04 (Charlton et al., 2019). For the purposes of testing the research hypotheses each of the nine emotional attributions were treated independently. A general linear mixed model with ratings nested within judges was built for each emotional attribution including emotional context, whether the target wept, and the interaction between these variables as fixed effect predictors in the models. Random effects were added to both the judge level variance as a random intercept and as a judge level random slope for the effect of weeping. There were five stages to the model building which are detailed in the supplementary materials. Model fit was assessed using the -2 log likelihood method and only significant improvements to the model fit were kept in the final model. The results will only address the final model with the estimates of the predictors and model improvement parameters during each stage of the model building found in the supplementary materials.

5.4 Results

5.4.1 Descriptive Statistics

A descriptive account of the means of the emotional attributions as a function of context provided the necessary starting point for building the models of emotional attribution. Emotional judgements were aggregated across both judges and targets. The mean scores for each emotion judgement as a function of each context are provided in table 5.2. There were a few noticeable trends in the data which guided the model building stage of the analysis. Judges attributed moderate to low levels of emotion, with sadness ratings in some contexts reaching a mean score above five. There is a strong similarity in the pattern of scores in the sad context compared to the no-context reference group. Sadness was the most intense emotion attributed in all contexts except the fear context for non-weeping targets. Finally, emotional contexts increased the intensity judgement for their corresponding emotion e.g., higher anger ratings in the anger context. Figure 5.3 shows the distribution of emotional attributions, there is a large negative skew and the majority of emotional attributions were scored below two. From this description we can see that attributions with a mean less than two should be considered ‘as not experiencing that emotion’. Therefore, scores above two can be considered as important.

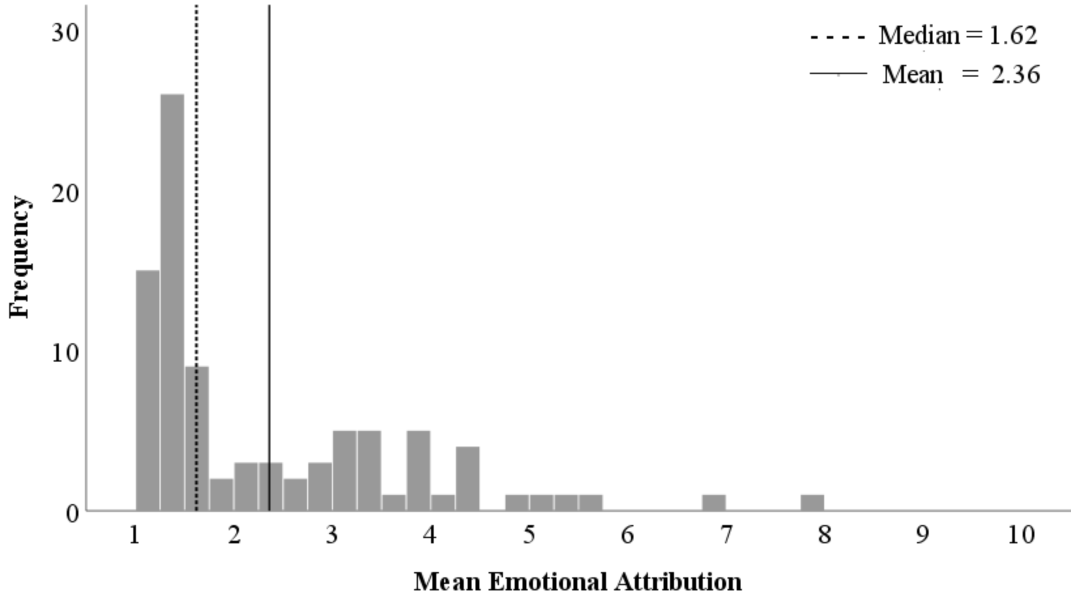

Figure 5.1. Distribution of mean emotional attributions across all contexts

Table 5.2. Means (standard deviations) of the emotion ratings (1 low -10 high) attributed to the targets as a function of the emotional context and whether the target wept provided prior to the judgements.

Emotion Attribution (1 low -10 high)	Emotion Context									
	No Context		Sad		Joy		Fear		Anger	
	Target Wept	Target Sad	Target Wept	Target Sad	Target Wept	Target Sad	Target Wept	Target Sad	Target Wept	Target Sad
Sadness	**5.61 (2.12)**	**4.29 (2.24)**	**7.95 (0.98)**	**5.21 (1.17)**	**5.36 (1.42)**	**3.16 (1.48)**	**4.25 (2.07)**	**2.24 (0.43)**	**6.93 (1.50)**	**4.34 (1.14)**
Happiness	1.37 (0.92)	1.47 (1.04)	1.62 (0.90)	1.41 (0.51)	**3.87 (1.59)**	**2.77 (1.23)**	1.28 (0.50)	1.43 (0.76)	1.25 (0.44)	1.11 (0.18)
Fear	1.40 (0.69)	1.42 (0.89)	1.47 (0.31)	1.45 (0.41)	1.43 (0.46)	1.26 (0.27)	**3.81 (1.59)**	**3.24 (0.93)**	**2.18 (0.54)**	**2.24 (0.91)**
Anger	1.40 (0.87)	1.49 (1.04)	1.29 (0.19)	1.34 (0.35)	1.19 (0.22)	1.20 (0.21)	1.42 (0.39)	1.41 (0.32)	**3.04 (1.05)**	**3.31 (1.08)**
Disgust	1.43 (0.76)	1.33 (0.68)	1.23 (0.22)	1.09 (0.14)	1.20 (0.25)	1.16 (0.30)	1.67 (0.74)	1.49 (0.44)	**3.46 (1.07)**	**3.42 (0.91)**
Amusement	1.20 (0.56)	1.17 (0.56)	1.19 (0.37)	1.26 (0.30)	1.58 (0.58)	1.38 (0.58)	1.68 (1.00)	1.59 (0.81)	1.17 (0.37)	1.17 (0.18)
Interest	**3.22 (2.28)**	**2.52 (1.79)**	**4.48 (1.48)**	**3.95 (1.00)**	**4.84 (0.80)**	**3.39 (0.99)**	**3.60 (0.78)**	**3.28 (1.17)**	**4.05 (1.18)**	**3.06 (1.07)**
Boredom	1.41 (1.01)	**2.84 (2.09)**	1.20 (0.49)	**2.63 (1.05)**	1.71 (0.78)	**3.76 (1.16)**	2.27 (1.08)	**3.96 (1.19)**	1.59 (0.78)	**2.98 (1.11)**
Relaxation	1.78 (1.16)	**2.25 (1.65)**	1.41 (0.27)	1.74 (0.51)	1.91 (0.49)	**2.39 (0.95)**	1.44 (0.63)	1.59 (0.50)	1.17 (0.39)	1.34 (0.27)

Note: Bold represents mean attribution above two.

5.4.2 Mixed effect models for each emotional attribution.

The final mixed level model for each emotional attribution is reported below. The full model building strategy and estimates of effect are available in the supplementary materials. The intercept in each of the models represents the emotional judgements for the reference group. In the following models this reference group was non-weeping targets when no context was given.

Happiness. Table 5.3 shows the intercept of the model, which represented predicted happiness attributions in no context condition for non-weepers, was very low. A random intercept significantly improved the model fit suggesting a *between-judge* difference in these attributions. This random effect explained 9% of the total variance. There was a fixed effect of context with happiness ratings significantly increasing in the joy context by 85%. There was no significant fixed effect of weepers on happiness scores but there was a random effect of weeping that showed there was a large *between-judge* effect accounting for about 17% of the total variance. There was a fixed effect interaction between weeping and joy context. When the target wept there was a significant increase in happiness scores but only in the joy context. To further explore the interaction, a random slope was added to the interaction between joy context and target weeping, figure 5.3 shows that while target weeping increased happiness ratings in the joy-context for most of the judges there were also some judges that reported no differences or reported lower happiness ratings when the target wept compared to the non-weeping target group. This is highlighted by the positive level one variance for target weeping which shows judgements made about weepers were far more varied in their happiness scores than judgements made about non-weepers.

Sadness. Sadness attribution had the highest intercept of all the nine emotions. This indicates that for non-weeping targets, when no context was given, sadness was the emotional category rated as most intense. There was a fixed effect of both a joy or fear context which significantly reduced the sadness scores by 30.7% and 53.5% respectively compared to the no context group. The anger or sad contexts did not significantly impact the sadness ratings when no context was provided for non-weeping targets. The random intercept in the model suggests *between-judge* variation in this group accounted for 17.5% of the total variation in sadness judgements. There was a fixed effect of target weeping with sadness scores increased for weeping targets by 29% with no context. The addition of a random slope for the effect of weeping did not significantly improve the model and the sadness ratings were more varied for weeping targets than for non-weeping targets. Three contexts significantly interacted with whether the target was a weeper or not. Weeping increased attributions of sadness in the sad context by 31.6%, the joy context by 19.6%, and the anger context by 30.7%. A random slope was added to the interaction between the sad context and target weeping. Figure 5.3 shows that the effect of weeping on predicted sadness ratings in a sad context was extremely consistent *between-judges*. Estimates of effect are shown for the final model in table 5.3.

Fear. There was very little fear attributed to non-weeping targets when no context was provided. There was a fixed effect of context with fear attributions significantly higher in a fear context (113%) or an anger context (48.7%). The addition of a random intercept showed that 24% of the total variance in fear judgements were accounted for by *between-judge* differences. There was no fixed effect or random effect of weeping but there was a fixed effect interaction, fear ratings increased for weepers but only in the fear context. To further explore the interaction a random slope was added, figure 5.3 shows that weeping increased in ratings of fear in a fear context for some but not all judges. Estimates of effect are shown for the final model in table 5.3.

Anger. There were very low ratings of anger when there was no context and a non-weeping target. There was a fixed effect of context with anger scores significantly increased when rated in an anger context by 129% compared to the no-context group. The addition of a level 2 random intercept shows *between-judge* differences account for 17% of the total variance. There was no fixed or random effects of target weeping on anger scores but there was a fixed effect interaction between anger context and target weeping. The interaction shows ratings made when the target wept in the anger context were lower than ratings when the target did not weep. To further explore the interaction a random slope was added, figure 5.3 shows that for most judges the addition of a weeping target to an anger context decreased predicted anger attributions but this was not the case for all judges. Estimates of effect are shown for the final model in table 5.3.

Disgust. Disgust ratings for non-weeping targets with no context were very low in the final model. There was a fixed effect of context with disgust ratings increased in the anger context by 136%, but not in the joy, fear or sad contexts. The addition of a random intercept shows that 17.9% of the variance in disgust ratings are accounted for by *between-judge* differences. There was no significant fixed or random effect of either target weeping or any fixed effect target weeping by emotional context interactions. A positive level 1 variance of target weeping suggest that for targets who wept, disgust ratings were more varied than the non-weeping targets. Estimates of effect are shown for the final model in table 5.3.

Boredom. Table 5.4 shows that boredom ratings for non-weeping targets when there was no context were high relative to other emotional attributions. These were significantly increased for non-weeping targets in the fear context by 39.3%

whilst the joy, anger and sad contexts had no significant fixed effect. A random intercept accounted for 19.7% of the total variance, suggesting a large amount of *between-judge* variance. There was a fixed effect of target weeping with weeping targets rated as significantly less bored with a 50.3% reduction in boredom ratings. There was also a random effect of target weeping, a random slope was added for the effect of weeping, figure 5.4 shows that there was convergence *between-judges* in the boredom ratings for the weeping targets. This is explained by weeping having the biggest effect on judges that rated boredom highest in non-weeping targets and confirmed by the complex level 1 variance which is much lower in weeping than non-weeping targets.

Interest. Table 5.4 shows the intercept for the final model of interest scores was higher than the basic emotion categories except sadness. This means that the non-weeping targets rated without context were seen as interested. The fixed effect of sad context significantly increased the interest attributions by 42.7% whilst joy, fear and anger contexts had no significant fixed effect on the interest scores. The addition of a level 2 random intercept showed that the *between-judge* differences accounted for the majority of the total variance, 59%. There was no significant fixed effect of target weeping but there was a random effect of target weeping represented by adding a random slope to the model. Figure 5.4 shows that there was great variety in both the scores made for weeping and non-weeping targets and that there was very little consensus as to the direction of the random effect *between-judges*. The small random effect suggests those judges who rated non-weeping targets highest in interest had a slightly larger increase in interest when the target was a weeper. The high covariance with the random intercept suggests the *within-judge* effect consistent across videos. There was no fixed effect interactions between target weeping and emotional context. Overall, interest judgements were judge specific.

Relaxation. Table 5.4 shows the intercept for relaxation attributions was very similar to the interest and boredom ratings. The addition of fixed effects for sad, fear and anger contexts significantly reduced the relaxation ratings by 29.2%, 39.2%, and 47.2% respectively. The joy context did not significantly change relaxation ratings. The addition of a level 2 random intercept showed that *between-judge* differences accounted for 27.2% of the total variation. There was a fixed effect for target weeping with ratings of relaxation lower in weeping targets than non-weeping targets. There was no random effect for relaxation ratings but the complex level 1 variance showed weeping target scores were less varied than non-weeping targets. There was a significant fixed effect interaction between fear context and when the target wept, relaxation scores increased but in the fear context only.

Table 5.3. Estimate of effects for the six basic emotion categories rated by the judges.

	Emotional Attributions											
	Happiness		Sadness		Fear		Anger		Disgust		Amusement	
Parameters	Est.	*S.E.*	Est.	*S.E.*	Est.	*S.E.*	Est.	*S.E.*	Est.	*S.E.*	Est.	*S.E.*
Fixed Effects												
Intercept *(β0)*	1.49	0.20	4.49	0.38	1.50	0.28	1.47	0.22	1.43	0.21	1.19	0.16
Sad Context	-0.06	0.24	0.71	0.44	-0.03	0.32	-0.13	0.26	-0.36	0.24	0.07	0.18
Joy Context	1.27**	0.24	-1.38*	0.44	-0.22	0.32	-0.30	0.26	-0.23	0.24	0.25	0.18
Fear Context	-0.32	0.24	-2.40**	0.45	1.70**	0.32	-0.08	0.26	0.03	0.25	0.30	0.18
Anger Context	-0.39	0.24	-0.28	0.44	0.73*	0.32	1.90**	0.26	1.95**	0.25	-0.06	0.18
Target Wept	-0.13	0.30	1.31**	0.31								
Target Wept*Sad Context	0.38	0.36	1.42**	0.44	0.04	0.20	-0.07	0.18	0.17	0.18	-0.03	0.14
Target Wept*Joy Context	1.27**	0.36	0.88*	0.44	0.15	0.20	0.01	0.17	-0.03	0.18	0.15	0.14
Target Wept*Fear Context	0.50	0.37	0.70	0.45	0.71**	0.21	0.06	0.18	0.25	0.19	0.31*	0.15
Target Wept*Anger Context	0.29	0.36	1.38*	0.45	-0.02	0.20	-0.40**	0.18	0.01	0.19	0.12	0.15
Variance Components												
Lvl 2: Random Intercept *(U0j)*	0.23	0.09	0.93	0.20	0.61	0.11	0.35	0.07	0.31	0.07	0.17	0.04
Lvl 2: Random effect: Target Wept *(U1j)*	0.41	0.19										
Lvl 2: Covariance	-0.09	0.10										
Lvl 1: Residual *(e0ij)*	1.62	0.11	4.37	0.29	1.94	0.09	1.70	0.11	1.42	0.10	0.70	0.05
Lvl 1: Residual: Target Wept *(e1ij)*	0.74	0.20					-0.33	0.15	0.59	0.16	0.69	0.10
Fit Statistics												
-2 LL (Number of parameters)	3888.01 (13)		4883.71 (11)		3926.96 (9)		3634.89 (9)		3724.45 (10)		3151.64 (13)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

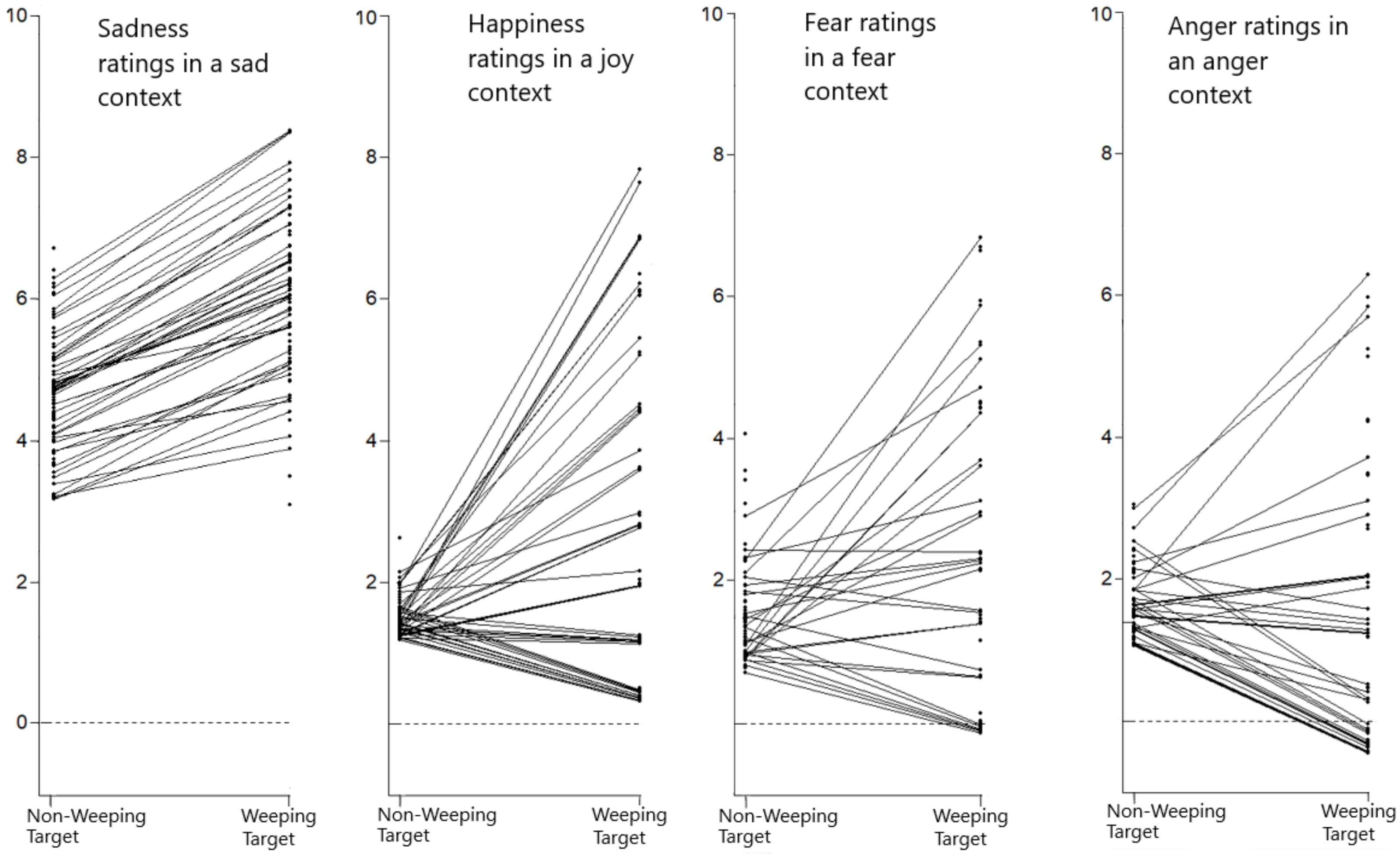

Figure 5.2. Random slope for the interaction between emotional context and weeping for context congruent predictions (each line/point represents one judge)

Table 5.4. Estimates of effect for the two epistemic emotions and relaxation rated by the judges.

	Emotional Attributions					
	Boredom		Interested		Relaxation	
Parameters	Est.	*S.E.*	Est.	*S.E.*	Est.	*S.E.*
Fixed Effects						
Intercept *(β0)*	2.90	0.45	2.67	0.54	2.50	0.32
Sad Context	-0.27	0.52	1.14*	0.59	-0.73*	0.35
Joy Context	0.81	0.52	0.66	0.58	-0.08	0.35
Fear Context	1.14*	0.52	0.51	0.59	-0.98*	0.35
Anger Context	0.14	0.52	0.21	0.59	-1.18**	0.35
Target Wept	-1.46**	0.44	0.50	0.52	-0.50**	0.17
Target Wept*Sad Context	0.07	0.52	0.32	0.60	0.22	0.24
Target Wept*Joy Context	-0.49	0.52	0.99	0.60	-0.03	0.24
Target Wept*Fear Context	-0.22	0.53	0.15	0.60	0.57*	0.25
Target Wept*Anger Context	-0.02	0.53	0.64	0.60	0.45	0.24
Variance Components						
Lvl 2: Random Intercept *(U0j)*	1.35	0.37	2.30	0.39	0.72	0.11
Lvl 2: Random effect: Target Wept *(U1j)*	-1.11	0.36	0.10	0.32		
Lvl 2: Covariance	1.05	0.40	1.61	0.48		
Lvl 1: Residual *(e0ij)*	5.51	0.39	3.54	0.18	1.93	0.13
Lvl 1: Residual: Target Wept *(e1ij)*	-3.48	0.42	2.67	0.54	-0.93	0.15
Fit Statistics						
-2 LL (Number of parameters)	4466.97 (13)		4748.91 (12)		3630.79 (11)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

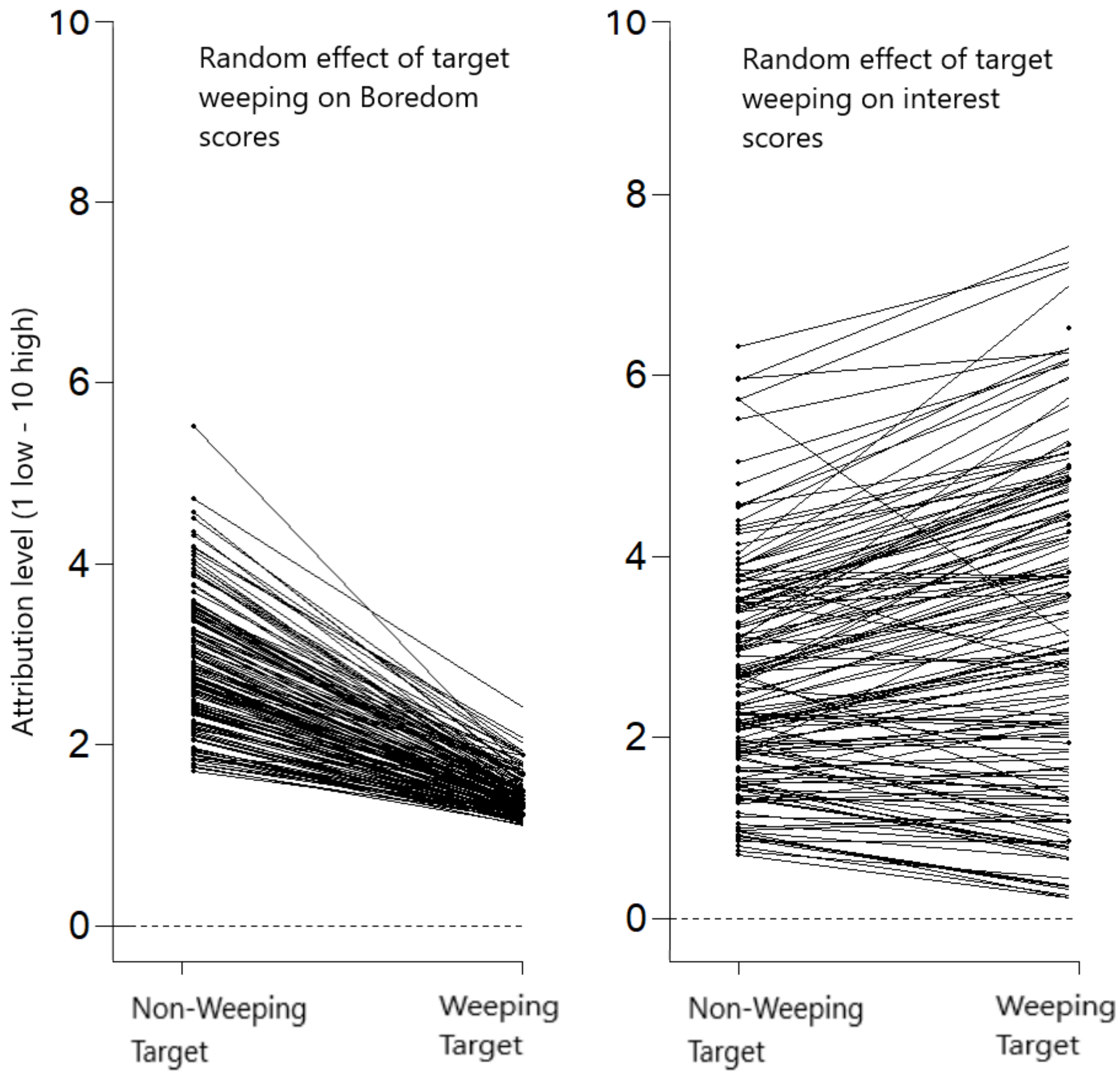

Figure 5.3. Random effect of weeping on boredom and interest predictions (Each line/point represents one judge).

5.5 Discussion

In summary, emotional attributions were strongly affected by whether the target wept *and* the emotional context. Judges rated targets as sad and the presence of weeping increased sadness attributions regardless of the emotional context. In other words, judges correctly detected the targets were sad. Furthermore, context specific attributions increased with the addition of emotional context and weeping further increased the congruent emotional attributions for three contexts: joy, sad and fear.

However, the target weeping reduced anger attributions in the anger context. Therefore, judges saw weeping targets as feeling a blend of both sadness and the emotion suggested by the emotional context.

5.5.1 Does emotional context effect emotional attributions?

Overall, we found strong support that emotional context was important in the perceptions of emotions in others. The addition of an emotional context substantially changed the judges' perception of the targets' emotions. When target videos were rated with no-context they were rated as being sad, with slightly lower levels of boredom, interest and relaxation. Without a context, judges attributed almost no happiness, fear, anger, disgust and amusement to the targets. When a joy context was added, happiness ratings increased whilst sadness ratings decreased. The sad context increased the interest scores whilst decreasing the relaxation scores but had no effect on sadness scores independent of target weeping. The fear context increased fear and boredom ratings whilst reducing relaxation ratings and strongly decreasing sadness ratings. The anger context increased both anger and disgust ratings and reduced the relaxation scores.

Attributions made when there was no context were very similar to the attributions made in the sad context. Given that all of the targets were actually watching sad films it suggests without context the judges were able to detect what type of film the target was viewing. Targets were watching sad films, they felt sad and this was perceived accurately by the judges. It is for this reason the sad context had little effect on the emotional attributions, it was synonymous with no context. This seems to suggest that the addition of a context is having a top-down effect on the judgement. There is strong evidence that context is processed automatically and alters the location on the face we focus on (Barrett et al., 2011; Gendron et al., 2013). The context is therefore producing an expectancy effect with judges looking for cues that confirm the emotion they think the target should be experiencing. For example, when anger is primed by context eye tracking data shows perceivers focus more on the eyes, whereas, when disgust is primed perceivers are looking at both the eyes and mouth (Aviezer et al., 2008). Furthermore, this would suggest that some cues are congruent or incongruent with the expected emotional expression. For instance, disgust is rarely cited as antecedent for emotional tears (Vingerhoets & Cornelius, 2001). When the behaviour of the target is incongruent with the expected emotion it seems that judges are incorporating both the expected emotion from the context and decoding the signals from the expression creating a blend of emotions. This is observed in our data, even though sadness scores were reduced in the joy, fear and anger contexts judges still rated the targets as sad.

5.5.2 Is there *between-judge* consistency in emotional attributions as a function of context?

The judges rated some but not all the target video context pairings, it was therefore important to assess whether there were judge-level dependencies in the data. This was done by structuring the judgements within judge and modelling the dependencies as a random intercept. The addition of a random intercept significantly improved all the nine models of emotional attributions. This suggests there was significant *between-judge* differences or in other words judges themselves exhibited individual differences in how they perceived the targets. The variation accounted for ranged from 9% in sadness ratings to an extremely large 59% for interest scores. The amount of variance accounted for by *between-judge* differences was higher in the epistemic emotions and relaxation compared to the six basic emotions. This may be because the basic emotions have a stronger relationship to facial expressions whether actual or believed by the judge. The amount of variance accounted for by the hierarchical modelling shows the importance of using statistical methods that don't treat *between-judge* variance as measurement error but as an important source of variation that must be accounted for. Accounting for this source of variation allows us to make a judgement on the reliability of the signal value of the stimuli. Where the judge level variation is low, such as in sadness, we can make the assumption that the signal value of the target is being interpreted with a level of consistency.

5.5.3 What is the role of target weeping on emotional attributions?

We found strong support that weeping targets where perceived differently than non-weeping targets. When the target was a weeper there was an increase in sadness attributions and a reduction in boredom and relaxation ratings. It is clear that even when an emotional context is used to prime the judge, weepers look sadder than non-weepers. This is consistent with the literature on the perception of weeping, judges see weeping as a sadness signal (Balsters et al., 2013; Hendriks & Vingerhoets, 2006; Provine et al., 2009; Reed et al., 2015; Vingerhoets et al., 2016). We found strong support for the tearing effect (Provine et al., 2009) and our effect size was larger than previous studies. We found sadness attributions increasing by roughly 30%, when no other emotional context is provided, compared to non-weeping targets. One major factor in this increase in effect size is probably our use of dynamic stimuli *and* actual episodes of weeping. Whilst our data replicate the effects found in the current literature and shows how the tearing effect is increased when using dynamic stimuli, it is important to note there could be other factors driving the differences. Where our stimuli were naturalistic, in a sense that no digital editing took place, we used actual weepers and non-weepers, a range of other factors such as facial expressions may be influencing the differences. Weeping doesn't occur in isolation from other behaviours, weepers report higher levels of sadness in the laboratory compared to non-weepers (Gross et al., 1994) and therefore may express sadness with more intensity. It is likely that the large differences between weepers and non-weepers is a combination of multiple factors of which weeping is major one.

Weeping also has an effect on the attributions of cognitive engagement. A reduction in boredom scores reflects judges' ideas that weeping requires a level of engagement on behalf of weeper to the stimulus regardless of the emotional context. This makes sense when we consider weeping is thought of as a very hard behaviour to generate on command (Provine, 2012). Weeping normally has a causal trigger and there needs to be some engagement with that trigger to induce weeping. The attributions of relaxation offer an interesting take on the current literature on the *intra*individual effect of crying. Despite the folk belief that crying reduces arousal or negative affect (Gračanin et al., 2014; Sharman et al., 2018), weepers were rated as being less relaxed, despite strong lay beliefs that weeping brings about emotional catharsis (Cornelius, 1981; Sharman et al., 2018; Sharman, Dingle, Baker, et al., 2019). This fits with the physiological data that at the point of weeping there is increased arousal (Gračanin et al., 2014; Gross et al., 1994; Hendriks et al., 2007). What is not clear from the data is whether it is tears or other factors that are acting as the signal for less relaxation. The relationship between weeping and relaxation warrants further examination and may help us better understand whether there is any cathartic effects of weeping.

5.5.4 How does the effect of weeping differ between judges?

The addition of a random slope for the effect of weeping improved the model fit for happiness, boredom and interest ratings. For happiness ratings the negative covariance shows that the random slopes diverge, the judges who scored happiness lowest with a non-weeping target showed the largest decrease in happiness ratings when the target was a weeper. However, the covariance and random effects were small and coupled with the non-significant fixed effect of weeping would suggest a varied response from judges with some rating weepers happier than non-weepers and some rating weepers as less happy than non-weepers. This makes sense because these effects are not taking into account the emotional context which played a role in the amount of happiness attribute to the target.

Boredom ratings showed the opposite effect, with weepers' scores converging compared to non-weepers. Scores for weepers had less variance, giving the figure the appearance that the lines converge or fan inwards. The large positive covariance and large negative random effect shows judges with the highest boredom ratings for non-weepers had the biggest decrease in ratings when the target was a weeper. This suggests that weeping is acting as a reliable cue to the targets' engagement with the stimuli. This again makes sense as crying is considered a very hard behaviour to fake and is not under voluntary control (Provine, 2012); the participants are crying about something which suggests they are not bored. Interest ratings had a very large positive covariance or the fanning out pattern but a very small random effect. This means there was a very slight 'fanning out' of scores although coupled with both a small fixed and random effect suggests this was not very prominent.

The effect of weeping was also analysed by allowing complex level one variance. This separates the variance of judgements between weeping and non-weeping targets. Weeping targets showed less variance in scores for anger, boredom and relaxation compared to non-weepers. The opposite pattern was found for disgust, amusement and interest scores weepers had a larger variance for weepers compared to non-weepers. It seems that the critical factor with these judgements is the congruence between tears and emotional judgements. For instance, tears act as a social antagonist to anger and weepers are then generally rated as not angry and the judgements are clustered at the bottom of the scale. Which is of particular interest because females often highlight anger as a cause of weeping (Averill, 1983). Whilst expressions of disgust and amusement are not congruent with weeping and therefore creates a situation in which the behaviour is not matched to the context. This in turn leads to a wider range of judgements.

Overall, the addition of weeping to the a model as a random effect at both judge and target level highlighted that the signal value of tears is relatively stable across the basic emotion categories but not for the epistemic emotions and relaxation. The level one variance also highlighted the strength of weeping as a signal. Judgements that are congruent with weeping had scores clustered, but in instances where weeping was incongruent with the judged emotion we see a wide variance, indicating less agreement among judges.

5.5.5 Does the effect of weeping change in different emotional contexts?

We found some support that effect of weeping changes in different emotional contexts. Whilst emotional judgements congruent with the context increased, the weepers were still seen as sad. For each of the emotional contexts the related emotional judgement interacted with whether the target wept. For instance, targets who wept had significantly higher happiness scores but only in the joy context, significantly higher fear scores but only in the fear context and significantly lower anger scores but only in the anger context. Targets who wept were also rated as sadder in the sad, anger and joy context. Weeping clearly signals sadness *and* other emotions determined by the context. Judges are integrating all of the cues and rating the videos as a blend of sadness with the contextual emotion. This is the first time weeping has been shown to increase emotional attributions other than sadness. Emotional context is playing a role in how judges rate weeping, although, judges still perceived increased sadness. These interactions were explored graphically by adding a random slope and whilst for sadness scores the effect is similar for each judge there was a *between-judge* difference in the joy, anger, and fear contexts. Not every judge saw additional happiness for weepers in the joy context some rated weepers as less happy. What is still unclear is why some judges saw weepers as experiencing an increased intensity of the context emotion whilst others just saw sadness. One major factor could be the intensity of weeping in the target videos. Some weepers just looked sadder whilst in others there was more ambiguity, and this could be driving the differences. The other major factor is that the videos the targets watched were rarely just generating sadness, some films included moments of amusement, disgust and fear. The blend of emotions perceived by the judges may reflect the lack of purity in the original emotion induction procedure. This also reflects naturalistic emotions which are very rarely intense and pure. Everyday episodes of emotion are normally low intensity and are often amalgamations of multiple basic emotions (Scherer et al., 2004). There was also a significant, although small, increase in amusement and relaxation scores in the fear context for weeping targets. This perhaps comes from the low level of weeping in times of fear. The fear context is then somewhat incongruent with weeping and judges are seeing this emotional blend as containing elements of amusement. The effect, however, was small and further investigation would be needed to assess whether this is a real effect or a byproduct of the stimuli used.

5.5.6 Methodological considerations and future directions

One major factor of the methodology used in this study is the use of videos of real weepers. Whilst we consider this a strength of the study, it does have some drawbacks. For instance, we cannot disentangle signal functions of weeping from other elements that may have been present in the target videos containing weeping compared to the target videos containing no weeping. It is probable that other cues have influenced the judges including facial expressions and body language. It would be therefore important to conduct further analysis on the target videos, specifically FACS or behavioural coding. Furthermore, using videos of the weepers prior to weeping will also help to understand if there are any target specific effects driving the emotional attributions.

Secondly, we used scenes from films associated with particular emotions, although judges were not told what emotion the researchers were priming. This means it is uncertain whether the difference between judges was due to perception of the target's emotions or differences in the perception of the emotional contextual. We chose not to have judges indicate their own levels of affect to limit the judges' emotional reflection which may in itself have generated emotions in the judges. Going forward, it would be important to gather data from judges on whether they felt changes to levels of their own affect whilst watching either the contextual or target videos.

5.5.7 Conclusion

The main aim of this experiment was to address the role of emotional context on the perception of weeping. Ratings made with a sad-context were very similar to those made when no context was given. This is important because all of the target videos were made during the watching of sad videos, therefore, despite information to the contrary, judges accurately perceived the targets as sad. However, the addition of emotional context strongly influenced the judges' emotional attributions. Joy, anger and fear contexts reduced sadness scores but increased the emotional attributions in line with the context. Weeping increased this effect for joy, sadness and fear whilst anger scores were reduced in an anger context by weeping. Regardless of the context, weeping also increased sadness attributions. Across all effects there was a reasonable amount of judge level variance apart from the relationship between weeping and sadness. It therefore seems appropriate to suggest weeping primarily acts as a cue to sadness unless there are cues to other emotions where the weeping is seen as a product of both sadness and emotions prompted by the context. This paper acts as the first one to find perceptions of weeping associated with increases in emotions other than sadness and as such is more in line with peoples real world experiences with weeping (Cornelius, 1981). This paper also shows that the addition of an emotional context can modulate how judges view powerful and stereotypical emotional behaviours.

Chapter 6: General Discussion

The overarching aim of this program of research was to investigate the intraindividual and interindividual functions of weeping using a range of physiological and psychological metrics. Overall, this research highlights the social nature of weeping. Across the empirical chapters we have shown that weeping should be considered an important behaviour during crying with its own physiological response; the response was not tied to underlying affect but to the process of weeping. We have also shown that the signal value of tears can be modified with the addition of contextual information in a top-down fashion. The results suggest weeping has a strong interindividual function but found no evidence of weeping leading to emotional relief. This discussion provides an overview of the main findings, the theoretical and practical implications for our understanding of weeping, and the implications for the wider emotion literature. Finally, we will then discuss some of the methodological limitations and avenues for future research.

6.1 Summary of main findings and implications

6.1.1 Intraindividual function of weeping

Despite folk psychology and the media suggesting crying has health benefits that release stress and help restore physiological and emotional homeostasis the empirical evidence has been mixed (Cornelius, 1981; Vingerhoets & Cornelius, 2001). A paradox exists whereby crying increases negative affect and arousal at the time, but retrospective accounts often indicate crying improved people's mood (Gračanin et al., 2014; Vingerhoets & Bylsma, 2016). The intensity of crying is often a key difference between laboratory induced crying, which is often mild and does not include weeping, compared to the crying people recollect in retrospective studies, which is often intense and includes weeping. Given that weeping is common in retrospective reports and not in laboratory induced crying, we investigated whether weeping explains the paradox of crying. This was investigated across two experiments using both psychological and physiological metrics. We found no evidence weeping explained the paradox of crying and, in fact, found weeping to have a response above and beyond any other crying behaviour. Our results were largely consistent with previous findings. In chapter three weepers reported greater negative affect, and there was increased facial temperatures and lower respiration rates compared to non-weepers (Gross et al., 1994; Ioannou et al., 2016; Vingerhoets, 2013). Unlike much of the previous findings, we failed to find any differences in cardiac measures or electrodermal responses (Gross et al., 1994; Sharman, Dingle, Vingerhoets, et al., 2019). We suggest that a reason for this is because we had a range of low intensity crying behaviour in the non-weeping group. This meant that the non-weeping group were likely not a non-crying group, therefore, the non-weeping group still responded physiologically during the sad film. This led to similar cardiac and electrodermal levels between weepers and non-weepers. However, despite this, weepers facial temperature increases were significantly larger than the non-weeping group.

Chapter four explored the intraindividual function further by addressing the role of tear suppression on psychophysiological arousal. Emotional suppression is linked to increased physiological arousal (Gross & Levenson, 1993), however, only two studies have addressed the physiology of tear suppression and neither of them provided evidence that there was active tear suppression during the experiments (Kraemer & Hastrup, 1988; Labott & Teleha, 1996). If weeping does have psychophysiological benefits, we would expect reduced arousal in weepers compared to suppressors. We found the opposite; tear suppression was related to reduced arousal, and weeping, regardless of whether participants were asked to suppress weeping or not, was related to increased facial temperatures, increased heart rate and increased skin conductance. The participants who successfully suppressed weeping were characterised by a lack of physiological responses. These data are not consistent with the previous literature in tear suppression or the wider emotional suppression literature (Gross, 1998; Gross & Levenson, 1997; Kraemer & Hastrup, 1988; Labott & Teleha, 1996). Emotional suppression is often associated with increased physiological arousal due to the effects of cognitive load (Gross, 2013). We suggest that any effect on physiology on suppression may be masked by the large physiological responses when weeping. Therefore, we found no response in successful tear suppressors *relative* to the weepers. The previous literature on emotional suppression may then be distorted by the mildness of the emotions being suppressed. In these studies, the physiological response of cognitive effort is large *relative* to the physiological response to a mild emotion, whereas in chapter four, the physiological response to weeping was larger than any other influence on physiology, including tear suppression.

Across chapters three and four, we found no evidence that there was an intraindividual function of crying, at least in the short term. Therefore, it is unlikely that the intensity of weeping explains the paradox of crying (Gračanin et al., 2015). We found the opposite, higher intensity crying led to larger psychophysiological responding. There is some evidence that different crying behaviours may be related to different functions. Whilst weeping may work on an interindividual level acting as a signal, the reduction in breathing associated with sobbing may act more on an intraindividual level reducing arousal (Gračanin et al., 2014; Sharman, Dingle, Vingerhoets, et al., 2019). In our studies we found no evidence that weeping led to mood improvements, however, we did not measure sobbing behaviour. Sobbing is also related to more intense bouts of crying (Gračanin et al., 2015; Vingerhoets et al.,

2000) so theoretically, this would be an interesting avenue to explore. What the data are showing is that crying is not a unitary process made up of a range of different behaviours which show large amounts of variation both between people and between situation.

Weeping caused dramatic increases in facial temperature. The thermal increases were in the absence of any large changes to the cardiorespiratory or electrodermal systems. The thermal response correlated strongly with relaxation scores, participants who were the least relaxed reached the hottest temperatures. In chapter four, super-criers who successfully suppressed tears showed no physiological response, whereas the super-criers that wept had large temperature, heart rate, and electrodermal increases, suggesting a strong SNS influence at the point of weeping. These changes were in the absence of any psychological differences, suggesting weeping and not the underlying affect is driving the response. The implications of chapters three and four are primarily that by inducing only low intensity crying, which does not include weeping, we may be missing a critical part of the crying response. This is especially important when investigating tear suppression where watery eyes are often associated with both crying and suppression (Kraemer & Hastrup, 1988; Labott & Teleha, 1996).

6.1.2 Interindividual function of weeping

People report experiencing a range of different emotions when crying, with the sadness family being the most common (Vingerhoets, 2013; Vingerhoets & Cornelius, 2001). While less common than sadness, emotions including anger, frustration, stress, feeling moved, and joy, are all seen as having the potential to induce tears if the emotion is sufficiently intense (Landmann et al., 2019; Vingerhoets et al., 2000, 2016). Despite the range of emotions that can induce crying, tears seem to only signal sadness (Ito et al., 2019; Provine et al., 2009; Reed et al., 2015). Known as the 'Tearing Effect', the addition of tears to a face increase attributions of sadness and increases the level of social support people are willing to give (Provine et al., 2009). The tearing effect is extremely robust and has been replicated multiple times, however, judgements are often made without any contextual information (Zickfeld et al., 2018). To understand why tears signal sadness despite being associated with a range of emotions we investigated whether the addition of an emotional context as the cause of tears changed their signal value. Our results found evidence of the tearing effect *and* an increase in the emotional attributions that were congruent with the emotional context. The effect of weeping in joy, anger and fear contexts showed a large amount of judge level variance. For instance, in a joy context, some judges found weepers looked happier than non-weepers whereas some saw them as less happy. Overall, this suggests that there is a top-down effect of context on emotional attributions, which varied between judges.

Regardless of the emotional context, sadness ratings were always high. Given that all the target videos used were of people watching sad films (taken from chapter 3's participants), the judges were accurately decoding the visual signals. Whilst the addition of joy or fear context lowered sadness ratings, judges were still detecting sadness. The relationship between tears and sadness has been shown to be relatively automatic and happens pre-attentively (Balsters et al., 2013). Our data (Chapter 5) supported these findings regardless of emotional context, weepers were perceived as sadder than non-weepers. From our data, it seems that tears signal sadness and the context asserts a top down influence. We were able to modulate the emotions the judges attributed to weepers by adding emotional context. This is an important implication given that the majority of studies use stimuli devoid of context and in a real world setting weeping is embedded in context.

The results of our study are consistent with the findings from the literature that tears are perceived as a signal of sadness (Provine et al., 2009; Zickfeld et al., 2018). However, our data show it is possible, with the addition of context, to alter the perception of tears. Therefore, it may be more appropriate to suggest tears act as an honest signal of emotion and their decoding is an interaction between the target, the judge and contextual influences (Funder, 2012). Because our data only used sad weepers, we cannot rule out that judges were using a range of signals to attribute sadness, for instance weepers may have displayed more intense facial expressions associated with sadness compared to the non-weeping targets. Because our target videos were of naturalistic episodes of weeping, any differences between them and the non-weeping targets are likely to reflect differences that naturally exist. Overall, our results are consistent with current understanding on facial expressions where context modulates attributions (Barratt et al., 2016; Calbi et al., 2017; Mobbs et al., 2006). The largest effects of context are found when the facial expression is ambiguous or showing no clear emotional response (Barratt et al., 2016), however, tears are not wholly ambiguous. Tears act as an honest signal of emotion and are normally perceived as being from the sadness family of emotions (Vingerhoets et al., 2016). Ambiguity is introduced due to the wide range of situations may bring about weeping (Vingerhoets et al., 2001; Vingerhoets & Bylsma, 2016). We created a situation where the signal is incongruent with the context and find variance in the judgement of the expression. Some judges rated the targets as feeling a mix of sadness and the contextual emotion, some relied more on the context whilst others relied more on the video of the face. It will be important moving forward to disentangle this mix of causality. Importantly, what we have shown is that tears are interpreted in context.

6.1.3 Wider implications in emotion theory

This program of research also informs the wider debate on the physiology of emotion and emotional expressions. The organisation of physiological responses during emotions has long been debated (Lindquist et al., 2013). Although some theories of emotion suggest there are coordinated patterns of physiological responses unique to each emotion, these ‘fingerprints’ are yet to be identified (Siegel et al., 2018). There are always multiple influences on physiology, of which, cognitive effort and levels of attention are strongly related to heart rate responses (Lacey et al., 1963). Chapter two of this thesis investigated whether the mode of induction explained heart rate responses by conducting a comprehensive review of the psychophysiology and emotion literature. We found that if the emotion induction procedure involved the intake of information from the environment, e.g., films or pictures, heart rate decreased regardless of the emotion. Furthermore, if the induction method involved the mental reconstruction of an event e.g., remembering an occasion, heart rate increased regardless of the emotion. Heart rate response was a product of *how* we induce emotions and not *what* emotion. We suggest that attention may dominate affect due to the low intensity emotions generated in most laboratory emotion inductions.

To date there have been multiple meta-analyses trying to locate emotional fingerprints with limited success (Cacioppo et al., 2007; Kreibig, 2010; Lench et al., 2011; Siegel et al., 2018; Stemmler, 2004). However, by comparing emotion that have been generated using different induction procedures we may be comparing apples and oranges. It is generally understood that the mode of induction is a critical feature of how we interpret physiological responses during emotions (McGinley & Friedman, 2017); however, we are the first to provide a framework to predict direction of heart rate based on classic cognitive psychology literature of attention

(Lacey & Lacey, 1974; Lacey et al., 1963). The intake-rejection literature is extensive but dated (Chapter 2, Carroll & Anastasiades, 1978). Currently, cognitive psychologists prefer defining the intake-rejection hypothesis as inward vs. outward directed attention (Bridewell & Bello, 2016); however, these terms are yet to be discussed in the emotion literature. The results of our review fit well with idea of ‘emotion populations’ and that variance both *within* and *between* people is an expected outcome (Siegel et al., 2018).

The methodological implications of this research are twofold. Firstly, using an appropriate baseline that accounts for the physiological response to the induction method is critical, and identifying ways to generate more intense emotions in the laboratory might help reveal emotion related physiological responses. Using a baseline that matches the cognitive demands on the emotion induction method has long been identified as an important experimental control (Jennings et al., 2007). Despite this, a resting baseline is the popular choice in emotion research (Kreibig, 2010). Using a resting baseline means that the physiological response to attentional demands and emotion are confounded. The use of a ‘vanilla’ baseline is relatively simple when inducing emotions using intake stimuli such as films or pictures, where an emotionally neutral version is easily identified. However, this may be more difficult when using memories as a neutral memory due to the strong links between emotion and memory recall (V. R. LeBlanc et al., 2014; Tyng et al., 2017). What is critical going forward is a greater appreciation on how we can untangle the causal elements of physiological responses

The intensity of emotions generated in the laboratory is generally low (Chapter 2, Wilhelm & Grossman, 2010). At low intensity there is almost no coherence between behaviour, subjective affect and physiology, whereas during intense emotions the level of coherence improves (Cowen & Keltner, 2017; Mauss et al., 2005). A similar pattern may be present in the boundaries between emotional categories. The boundaries between the emotions may become less ‘fuzzy’ and more distinct as the emotion intensity increases (Siegel et al., 2018). Categorising emotion intensity is extremely difficult, the current literature rarely reports intensity of emotion in a consistent manner which has made cross-study comparisons of emotional intensity problematic (Siegel et al., 2018; Zelkowitz & Cole, 2016). In chapters three and four of this thesis we employed an idiographic approach to emotion induction. The idiographic induction technique produced intense emotions which were reflected in the increased level of weeping across both studies compared to traditional nomothetic methods (Ioannou et al., 2016; Vingerhoets & Cornelius, 2001). Allowing participants to indicate which films will induce a strong emotion increases the likelihood that the film will generate a strong emotion (Kuo et al., 2014). Therefore, we have changed the focus of the study from being about a single stimulus and varied emotional outcomes, to a focus on a single emotional outcome with varied stimuli. We did not concentrate on what makes people weep, only that they did weep. We suggest this led to consistency in outcome and may lead to consistency in physiological response, we removed variance due to attributions of the stimuli. Consistency of response is extremely rare in the emotion literature with variation between participants often dominating variation between groups (Mauss et al., 2005; Reisenzein et al., 2013; Siegel et al., 2018). Although further research is required to understand how to appropriately use the idiographic induction technique in experimental paradigms, we believe this approach will be beneficial to emotion researchers.

There is also a vigorous debate on the nature of emotional expressions and to what degree they represent emotion readouts or are active social tools (Buck, 1994; Crivelli & Fridlund, 2018; Fernández-Dols & Russell, 2017; Scarantino & Griffiths, 2011). A large portion of the criticism from BEV theorists stems from the difficulty people have identifying and categorising emotional expression, this difficulty exists even when the prototypical expressions are used (Aviezer et al., 2008; Crivelli & Fridlund, 2018). The accuracy of judges is increased when additional sources of information are included with the facial expression, such as body posture or details of the emotional context (Aviezer et al., 2008; Mobbs et al., 2006). However, in chapter five we found judges were extremely accurate in identifying sadness in our targets even when presented with contextual information that would suggest they may be experiencing emotions other than sadness. We suggest that the richness of our target videos, alongside the intense emotions felt by the targets, allowed judges to recognise sadness. Firstly, the target videos were dynamic and included body movements alongside naturalistic and un-prototypical facial expressions (Ambadar et al., 2005; Aviezer et al., 2008; Krumhuber et al., 2013; Nelson & Mondloch, 2017). Half the target videos also contained weeping, which appears to be a strong signal for sadness (Chapter five, Balsters et al., 2013; Provine, Krosnowski, & Brocato, 2009; Zickfeld, van de Ven, Schubert, & Vingerhoets, 2018). The expression of emotion is not a phenomenon restricted to static facial expressions but has often been studied that way. Overall, emotional expressions are dynamic in nature and are a combination of multiple signals from multiple sources. The affective sciences would then benefit by using more naturalistic stimuli.

6.2 Methodological considerations and future directions

6.2.1 Intraindividual function of weeping

This thesis addressed whether weeping was a critical factor that leads to the reported feeling of relief after crying. Chapters three and four showed, that in at least the short term, there was no evidence for this. However, there have been reports of benefits felt after approximately 90 minutes (Gračanin et al., 2015). A practical issue of using films as an induction method is that they often finish soon after the saddest moment, therefore unfortunately, it was not possible to continue measurements for an additional ninety minutes to track the participants physiology over this time period. Upon completion of films the participants had already spent up to 60 minutes connected to the psychophysiology equipment. Leaving them seated for an additional 90 minutes after this point, would be uncomfortable for both the participant and the researcher. The move to ambulatory recording systems will go some way to address this practical issue (Wilhelm & Grossman, 2010). It is only relatively recently that ambulatory physiological recording systems have provided the necessary accuracy to allow monitoring outside the confines of the laboratory. Future studies should look to use recording systems that allow for measurements over longer periods of time. This becomes especially important when combined with real world crying, which often includes the social elements that are important for crying to be remembered as being beneficial. Furthermore, the paradox of crying is also being assessed by addressing participants' implicit beliefs about crying (Sharman et al., 2018; Sharman, Dingle, Baker, et al., 2019). There is some indication that people who believe that crying improves mood, report more instances of mood improvement after crying (Sharman et al., 2018; Sharman, Dingle, Baker, et al., 2019). Given that people are often poor at remembering how they felt in the past (Kaplan, Levine, Lench, & Safer, 2016), the paradox of crying may exist because implicit crying assumptions alter the memory. By combining both beliefs about crying research with ambulatory psychophysiological assessment we will get a new understanding of whether crying reported as beneficial has any distinct physiological properties compared to crying not reported to improve mood.

6.2.2 Interindividual function of crying

We found strong evidence that tears signal sadness and that top-down modulation using emotional context can alter the judgements. What is not clear from our data is the role of tears generated from other emotions. Whilst judges were excellent at identifying the sadness in the targets, all targets were indeed sad. To properly understand the signal value of tears we would need to obtain judgements of weepers who are feeling other emotions, such as those weeping through joy or feeling moved, and non-emotional tears through ocular irritation (Stanislaw & Todorov, 1999). It is also possible that other signals on the face of weepers compared to non-weepers were driving emotional attributions. The videos obtained from the participants in chapter three, which were used in chapter five as target videos, are being used to create a database of weeping videos. These will be analysed using FACS and machine learning to identify future avenues of research. Although facial expressions seem to have little bearing on the signal value of tears (Ito et al., 2019; Reed et al., 2015), studies generally use fake tears and non-naturalistic target stimuli. Given the expression of emotion is dynamic and multimodal (Ambadar et al., 2005; Krumhuber et al., 2013; Nelson & Mondloch, 2017), it seems critical to use *actual* occurrences of weeping as the target stimuli. We may find weeping in *actual* occurrences of joy has its own distinct signal value but to date, research in the signal value of tears is generally restricted to ‘fake' stimuli.

Other than signalling emotion, the other interindividual function of tears is suggested to be about soliciting support (Crivelli & Fridlund, 2018; Gračanin, Krahmer, et al., 2018). This was not directly tested in our data but there is a robust effect of tears increasing willingness to offer social support (Balsters et al., 2013; Gračanin, Krahmer, et al., 2018; Hendriks, Croon, et al., 2008). These studies are again often studied without emotion context and with digitally added tears. A similar effect of top-down modulation occurs when the reason for tears is added, with 'appropriate' tears linked to increased support (Pauw et al., 2019). However, the emotional context of tears is yet to be addressed. Do tears of anger facilitate approach tendencies, when classically, anger is more commonly associated with avoidance in observers (Crivelli & Fridlund, 2018, 2019; Fridlund, 2014)? There is no doubt that weeping should be considered primarily a social signal, future research should make sure all elements of the social environment are considered when investigating the signal value of tears.

6.2.3 Emotion inductions

The use of the idiographic induction method led to a high rate of weeping (Chapters 3 and 4). The idiographic method restricts the use of within subjects designs which is often important in psychophysiological studies. Furthermore, having a range of stimuli meant that there was a large variance in the temporal elements of the emotion induction. For instance, some films induce the emotion slowly until climaxing with an expected emotional event, whilst others juxtapose a happy moment with a sudden sad moment. This introduces an element of temporal disparity between different emotional stimuli. Furthermore, participants watching the same film did not cry at exactly the same point in the film, although they were often clustered around a sad scene they had chosen. This was especially prominent when participants suppressed tears, the different regulatory abilities of the participants reflected different lengths of time after their chosen sad scene before they started weeping, if they wept at all. Although an attempt was made to give participants a similar amount of time watching the sad film, there was variance. This meant time watching the film was not an appropriate metric to standardise across participants, some participants watched up to one hour of the film, whilst others watched only 30 minutes. This meant we had to choose a feature of the recordings that could be used to synchronise across participants. We used the moment the tear became external to the eye as an anchor point, taking measures both pre- and post- this moment. For non-weepers a behavioural cue was not present, therefore we used the start of the sad scene as the anchor point. This makes comparisons between weepers and non-weepers difficult, as they are synchronised based on two different criteria. The use of an idiographic induction procedure will help to induce stronger emotions (Kuo et al., 2014) but further research is needed on developing a protocol for both the application and statistical analysis.

6.3 Conclusion

Weeping is the key component of crying but often does not take centre stage in crying research due to the difficulty in inducing tears in a laboratory. By focusing on weeping as the key component of crying we have highlighted how tear production is related to large and consistent temperature increases associated with SNS activity. This temperature increase is related to tear production and not underlying affect suggesting that by not making weeping a necessity in crying research, we may be missing crucial data in the crying response. Critically, tears are the major observable component in crying behaviour. We have also shown that the signal value of tears can be modulated by the emotional context. Tears were seen not only as a signal of sadness but as a signal of emotional intensity. Overall, these studies have shown weeping to be primarily a social signal as opposed to having any immediate benefit to the crier through cathartic or self-soothing mechanisms. Crying and weeping start out as an efficient social tool, and although many of the antecedents and behaviours change, crying in adulthood is still inherently social.

Chapter 7: References

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Appendix A: Supplementary Material (Chapter 5)

Number of judgements for each target-context pairing.

Table A.1 Number of ratings made for each target in the four emotional contexts.

Target	Sad Context	Joy Context	Fear Context	Anger Context	Total
Weeping					
W1	10	8	8	7	33
W2	10	9	7	9	35
W3	9	9	9	11	38
W4	9	10	8	8	35
W5	9	7	7	7	30
W6	9	8	9	8	34
W7	8	8	5	8	29
W8	8	8	8	8	32
W9	8	9	6	9	32
W10	7	6	9	7	29
W11	7	7	10	9	33
W12	8	9	8	9	34
W13	10	9	7	8	34
Non-weeping					
N1	10	8	7	8	33
N2	10	8	7	8	33
N3	7	9	10	8	34
N4	8	10	7	9	34
N5	7	7	12	9	35
N6	11	10	5	5	31
N7	9	7	9	8	33
N8	7	8	8	9	32
N9	8	10	9	9	36
N10	8	8	8	9	33
N11	7	10	7	8	32
N12	8	10	7	8	33
N13	8	9	8	7	32
Total	212	212	197	206	827

Model building strategy for each of the of the nine emotional categories.

For the purposes of testing the research hypotheses each of the nine emotional attributions were treated independent outcome variables and for that reason there was nine separate general linear mixed models. Table 3.1 shows that emotional context appeared to be having an effect on emotional attributions and therefore the baseline model included emotional context as a fixed effect predictor variable. In the following equations, $\beta 0i$ is the model intercept, the fixed effects of the model predictors are referred to by their variable name (e.g. Sad Context), U is used to represent random effects, and e is used to represent prediction residuals.

The variance of emotional attribution *(Y)* was partitioned into three potential sources, the level 2 *between-judge* random intercept variance, the level 2 *between-judge* effect of crying and the level 1 residuals. There was five stages of model building with each stage increasing in complexity. Each stage of the model building was checked for improved fit using a -2 log likelihood method and only the significant improvements were retained.

H1. Does emotional context effect emotional attributions

The baseline model (model 1, equation 1) was emotional attribution as the outcome variable *(Y)* from judgement (*i)* made by judge *(j)* in a hierarchical two-level variance component model with emotional context included as a fixed effect predictor variable. Emotional context was coded using four dummy variables comparing either sadness, joy, fear or anger contexts to the reference category which was emotional attributions made when no context was given (context [sadness, joy, fear, or anger] = 1, no context = 0)[7]. The intercept in the baseline model represents the mean emotion attribution made by the no context group.

Level 1: Yij (Emotion Attribution) $= \beta 0i$ +Sad Context ij +Joy Context ij +Fear Context ij +Anger Context ij

[7] This model is equivalent to a (GLM) multiple regression with sadness attribution as the outcome variable and emotional context as a predictor variable.

Level 2: $\beta 0i = \beta 0 + e0ij$

H2: Is the effect of context consistent across judges.

The first stage of the model building is to assess whether the data was hierarchically structured, or in other words, whether repeated judgements made by one of the judges are independent of their other judgements. This was achieved by adding a level 2 random effect to the model (model 2). The random effect was introduced by allowing the intercept to vary for each of the judges and modelled the *within-judge* dependencies (equation 2).

H3: What is the role of target weeping on emotional attributions

To test for the tearing effect, a fixed effect of whether the target video included a weeper was added as a fixed effect predictor. Judgements made on a weeping target were compared to judgements made when there was a non-weeping target (model 3, equation 3). This changed the interpretation of the intercept to the mean judgement in the no context group for non-weeping targets.

Level 1: Yij (Emotion Attribution) $= \beta 0ij$ + Sad Context ij + Joy Context ij + Fear Context ij + Anger Context ij

Level 2: $\beta 0ij = \beta 0 + U0j + e0ij$

Level 1: Yij (Emotion Attribution) $= \beta 0ij$ + Sad Context ij + Joy Context ij + Fear Context ij + Anger Context ij + Target Wept ij

Level 2: $\beta 0ij = \beta 0 + U0j + e0ij$ (3)

H4: Is there a between-target of between-judge variance on the effect of weeping.

The effect of weeping was allowed to vary *between-judge* by using a random intercept to allow for differences in judges perception of weeping (*U1j*, model 4, equation 4). We also allowed the effect of weeping to have complex level 1 variance to partition the *between-target* level 1 residuals. This was used to estimate the differences in variance of level 1 residuals in weeping targets compared to non-weeping targets (Model 5, equation 4).

$$\text{Level 1: } Yij \text{ (Emotion Attribution) } = \beta 0ij + \text{Sad Context } ij + \text{Joy Context } ij + \text{Fear Context } ij$$
$$+ \text{Anger Context } ij + \beta 1i \text{ Target Wept } ij$$
$$\text{Level 2: } \beta 0ij = \beta 0 + U0j + e0ij$$
$$\beta 1i \text{ Target Cried} = \beta 1 + U1j + e1ij \tag{4}$$

H5: Does the effect of weeping change in different emotional contexts.

The final stage was to add fixed effect interactions between the target weeping predictor and all of the different emotional context predictors (equation 5). In this final model (model 6) the intercept represented the grand mean of emotional attribution *(Y)* in judgement *(i)* by judge (*j)* when the target does not weep and there was no emotional context was provided.

$$\text{Level 1: } Yij \text{ (Emotion Attribution) } = \beta 0ij + \text{Sad Context } ij + \text{Joy Context } ij + \text{Fear Context } ij + \text{Anger Context } ij$$
$$+ \beta 1i \text{ Target Wept } ij + \text{Target Wept*Sad Context } ij + \text{Target Wept*Joy Conte}$$
$$+ \text{Target Wept*Fear Context } ij + \text{Target Wept*Anger Context } ij$$
$$\text{Level 2: } \beta 0ij = \beta 0 + U0j + e0ij$$
$$\beta 1i \text{ Target Cried} = \beta 1 + U1j + e1ij \tag{5}$$

Model progression tables for the nine emotion attributions

Table A.2. Estimate of effect and model fit parameters for happiness ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.43	0.11	1.43	0.19	1.26	0.20	1.39	0.18	1.34	0.19	1.49	0.20
Sad Context	0.12	0.15	0.13	0.22	0.12	0.22	-0.03	0.21	0.03	0.21	-0.06	0.24
Joy Context	1.88**	0.15	1.88**	0.22	1.88**	0.22	1.71**	0.21	1.70**	0.21	1.27**	0.24
Fear Context	-0.07	0.15	-0.07	0.22	-0.07	0.22	-0.23	0.21	-0.19	0.21	-0.32	0.24
Anger Context	-0.24	0.15	-0.24	0.22	-0.25	0.22	-0.42*	0.21	-0.34	0.21	-0.39	0.24
Target Wept					0.35**	0.09	0.40**	0.11	0.41**	0.11	-0.13	0.30
Target Wept*Sad Context											0.38	0.36
Target Wept*Joy Context											1.27**	0.36
Target Wept*Fear Context											0.50	0.37
Target Wept*Anger Context											0.29	0.36
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.23	0.07	0.24	0.07	0.15	0.08	0.24	0.09	0.23	0.09
Lvl 2: Random effect: Target Wept *(U1j)*							0.53	0.21	0.50	0.21	0.41	0.19
Lvl 2: Covariance							-0.02	0.10	-0.12	0.11	-0.09	0.10
Lvl 1: Residual *(e0ij)*	2.38	0.10	2.16	0.10	2.13	0.10	1.99	0.10	1.63	0.12	1.62	0.11
Lvl 1: Residual: Target Wept *(e1ij)*									0.76	0.21	0.74	0.20
Fit Statistics												
-2 LL (Number of parameters)	3969.88 (4)		3950.24 (5)		3935.69(6)		3920.30 (8)		3906.59(9)		3888.01 (13)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.2. Estimate of effect and model fit parameters for sadness ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.43	0.11	1.50	0.28	1.42	0.28	1.49	0.26	1.50	0.28	1.50	0.28
Sad Context	0.04	0.15	-0.01	0.30	-0.02	0.30	0.01	0.29	-0.01	0.30	-0.03	0.32
Joy Context	-0.08	0.15	-0.15	0.30	-0.15	0.30	-0.11	0.29	-0.15	0.30	-0.22	0.32
Fear Context	2.10**	0.15	2.05**	0.30	2.05**	0.30	2.07**	0.29	2.04**	0.30	1.70**	0.32
Anger Context	0.79**	0.15	0.72**	0.30	0.72*	0.30	0.75*	0.29	0.72*	0.30	0.73*	0.32
Target Wept					0.17	0.09						
Target Wept*Sad Context											0.04	0.20
Target Wept*Joy Context											0.15	0.20
Target Wept*Fear Context											0.71**	0.21
Target Wept*Anger Context											-0.02	0.20
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.58	0.10	0.59	0.10	0.81	0.16	0.59	0.10	0.61	0.11
Lvl 2: Random effect: Target Wept *(U1j)*							0.29	0.17				
Lvl 2: Covariance							-0.33	0.14				
Lvl 1: Residual *(e0ij)*	2.48	0.11	1.98	0.09	1.96	0.09	1.92	0.10	1.92	0.13	1.94	0.09
Lvl 1: Residual: Target Wept *(e1ij)*									0.11	0.19		
Fit Statistics												
-2 LL (Number of parameters)	4014.18 (4)		3939.03 (5)		3935.59(6)		3934.66 (7)		3938.79(6)		3926.96 (9)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.3. Estimate of effect and model fit parameters for fear ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.43	0.11	1.50	0.28	1.42	0.28	1.49	0.26	1.50	0.28	1.50	0.28
Sad Context	0.04	0.15	-0.01	0.30	-0.02	0.30	0.01	0.29	-0.01	0.30	-0.03	0.32
Joy Context	-0.08	0.15	-0.15	0.30	-0.15	0.30	-0.11	0.29	-0.15	0.30	-0.22	0.32
Fear Context	2.10**	0.15	2.05**	0.30	2.05**	0.30	2.07**	0.29	2.04**	0.30	1.70**	0.32
Anger Context	0.79**	0.15	0.72**	0.30	0.72*	0.30	0.75*	0.29	0.72*	0.30	0.73*	0.32
Target Wept					0.17	0.09						
Target Wept*Sad Context											0.04	0.20
Target Wept*Joy Context											0.15	0.20
Target Wept*Fear Context											0.71**	0.21
Target Wept*Anger Context											-0.02	0.20
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.58	0.10	0.59	0.10	0.81	0.16	0.59	0.10	0.61	0.11
Lvl 2: Random effect: Target Wept *(U1j)*							0.29	0.17				
Lvl 2: Covariance							-0.33	0.14				
Lvl 1: Residual *(e0ij)*	2.48	0.11	1.98	0.09	1.96	0.09	1.92	0.10	1.92	0.13	1.94	0.09
Lvl 1: Residual: Target Wept *(e1ij)*									0.11	0.19		
Fit Statistics												
-2 LL (Number of parameters)	4014.18 (4)		3939.03 (5)		3935.59(6)		3934.66 (7)		3938.79(6)		3926.96 (9)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.4. Estimate of effect and model fit parameters for anger ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.49	0.09	1.48	0.22	1.53	0.22	1.48	0.22	1.47	0.22	1.47	0.22
Sad Context	-0.18	0.13	-0.17	0.24	-0.17	0.24	-0.17	0.24	-0.17	0.24	-0.13	0.26
Joy Context	-0.30*	0.13	-0.30	0.24	-0.30	0.24	-0.30	0.24	-0.29	0.24	-0.30	0.26
Fear Context	-0.10	0.13	-0.06	0.24	-0.06	0.24	-0.06	0.24	-0.05	0.24	-0.08	0.26
Anger Context	1.68**	0.13	1.70**	0.24	1.70**	0.24	1.70**	0.24	1.68**	0.24	1.90**	0.26
Target Wept					-0.11	0.08						
Target Wept*Sad Context											-0.07	0.18
Target Wept*Joy Context											0.01	0.17
Target Wept*Fear Context											0.06	0.18
Target Wept*Anger Context											-0.40**	0.18
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.35	0.07	0.35	0.07	0.35	0.07	0.35	0.07	0.35	0.07
Lvl 2: Random effect: Target Wept *(U1j)*							0.00	0.00				
Lvl 2: Covariance							0.00	0.00				
Lvl 1: Residual *(e0ij)*	1.87	0.08	1.54	0.07	1.54	0.07	1.54	0.07	1.71	0.11	1.70	0.11
Lvl 1: Residual: Target Wept *(e1ij)*									-0.34	0.15	-0.33	0.15
Fit Statistics												
-2 LL (Number of parameters)	3712.10 (4)		3645.62 (5)		3643.86(6)		3645.62 (7)		3640.17(6)		3634.89 (9)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.5. Estimate of effect and model fit parameters for disgust ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.41	0.10	1.43	0.21	1.39	0.22	1.43	0.21	1.43	0.21	1.43	0.21
Sad Context	-0.24	0.14	-0.28	0.24	-0.29	0.24	-0.28	0.24	-0.29	0.23	-0.36	0.24
Joy Context	-0.22	0.14	-0.25	0.24	-0.25	0.24	-0.25	0.24	-0.24	0.23	-0.23	0.24
Fear Context	0.16	0.14	0.15	0.24	0.14	0.24	0.15	0.24	0.13	0.23	0.03	0.25
Anger Context	1.96**	0.14	1.95**	0.24	1.94**	0.24	1.95**	0.24	1.95**	0.23	1.95**	0.25
Target Wept					0.09	0.08						
Target Wept*Sad Context											0.17	0.18
Target Wept*Joy Context											-0.03	0.18
Target Wept*Fear Context											0.25	0.19
Target Wept*Anger Context											0.01	0.19
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.32	0.07	0.32	0.07	0.32	0.07	0.30	0.07	0.31	0.07
Lvl 2: Random effect: Target Wept *(U1j)*							0.00	0.00				
Lvl 2: Covariance							0.00	0.00				
Lvl 1: Residual *(e0ij)*	2.00	0.09	1.71	0.08	1.71	0.08	1.71	0.08	1.42	0.10	1.42	0.10
Lvl 1: Residual: Target Wept *(e1ij)*									0.59	0.16	0.59	0.16
Fit Statistics												
-2 LL (Number of parameters)	3785.00 (4)		3740.68 (5)		3739.39 (6)		3740.68 (7)		3726.95 (6)		3724.45 (10)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.6. Estimate of effect and model fit parameters for amusement ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	1.19	0.08	1.19	0.16	1.14	0.17	1.19	0.16	1.19	0.15	1.19	0.16
Sad Context	0.05	0.11	0.06	0.18	0.06	0.18	0.06	0.18	0.06	0.17	0.07	0.18
Joy Context	0.31**	0.11	0.32*	0.18	0.32	0.18	0.32	0.18	0.30	0.17	0.25	0.18
Fear Context	0.45**	0.11	0.45*	0.18	0.45*	0.18	0.45*	0.18	0.40*	0.17	0.30	0.18
Anger Context	-0.01	0.11	0.00	0.18	-0.01	0.18	0.00	0.18	-0.02	0.17	-0.06	0.18
Target Wept					0.10	0.07						
Target Wept*Sad Context											-0.03	0.14
Target Wept*Joy Context											0.15	0.14
Target Wept*Fear Context											0.31*	0.15
Target Wept*Anger Context											0.12	0.15
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.19	0.04	0.19	0.04	0.19	0.04	0.17	0.04	0.17	0.04
Lvl 2: Random effect: Target Wept *(U1j)*							0.00	0.00				
Lvl 2: Covariance							0.00	0.00				
Lvl 1: Residual *(e0ij)*	1.21	0.05	1.05	0.05	1.04	0.05	1.05	0.05	0.71	0.05	0.70	0.05
Lvl 1: Residual: Target Wept *(e1ij)*									0.70	0.10	0.69	0.10
Fit Statistics												
-2 LL (Number of parameters)	3249.64 (4)		3210.20 (5)		3207.66 (6)		3210.20 (7)		3157.68 (6)		3151.64 (10)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.7. Estimate of effect and model fit parameters for boredom ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	2.11	0.16	2.22	0.29	2.96	0.29	3.09	0.22	3.03	0.25	2.90	0.45
Sad Context	-0.22	0.22	-0.30	0.33	-0.25	0.32	-0.34	0.20	-0.25	0.24	-0.27	0.52
Joy Context	0.65**	0.22	0.55	0.33	0.56	0.32	0.43*	0.20	0.43	0.24	0.81	0.52
Fear Context	1.07**	0.22	0.99**	0.34	1.01**	0.33	0.90**	0.20	0.95**	0.24	1.14*	0.52
Anger Context	0.13	0.22	0.03	0.33	0.06	0.32	0.06	0.20	0.10	0.24	0.14	0.52
Target Wept					-1.55**	0.13	-1.64**	0.15	-1.61**	0.15	-1.46**	0.44
Target Wept*Sad Context											0.07	0.52
Target Wept*Joy Context											-0.49	0.52
Target Wept*Fear Context											-0.22	0.53
Target Wept*Anger Context											-0.02	0.53
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.55	0.15	0.54	0.14	2.06	0.38	1.39	0.37	1.35	0.37
Lvl 2: Random effect: Target Wept *(U1j)*							-1.73	0.36	-1.15	0.37	-1.11	0.36
Lvl 2: Covariance							1.29	0.37	1.09	0.40	1.05	0.40
Lvl 1: Residual *(e0ij)*	5.13	0.22	4.62	0.22	4.02	0.19	3.65	0.18	5.51	0.39	5.51	0.39
Lvl 1: Residual: Target Wept *(e1ij)*									-3.48	0.42	-3.48	0.42
Fit Statistics												
-2 LL (Number of parameters)	4793.89 (4)		4771.76 (5)		4631.81 (6)		4563.77 (8)		4469.58 (9)		4466.97 (13)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.8. Estimate of effect and model fit parameters for interest ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	3.03	0.18	2.90	0.57	2.49	0.59	2.64	0.54	2.65	0.54	2.67	0.54
Sad Context	1.19**	0.25	1.29*	0.61	1.25*	0.61	1.08	0.57	1.07	0.57	1.14*	0.59
Joy Context	1.06**	0.25	1.12	0.61	1.10	0.61	0.93	0.57	0.93	0.57	0.66	0.58
Fear Context	0.41	0.26	0.58	0.61	0.56	0.62	0.38	0.58	0.37	0.57	0.51	0.59
Anger Context	0.47	0.26	0.53	0.61	0.49	0.61	0.33	0.57	0.32	0.57	0.21	0.59
Target Wept					0.90**	0.13	0.98**	0.17	0.98**	0.17	0.50	0.52
Target Wept*Sad Context											0.32	0.60
Target Wept*Joy Context											0.99	0.60
Target Wept*Fear Context											0.15	0.60
Target Wept*Anger Context											0.64	0.60
Variance Components												
Lvl 2: Random Intercept *(U0j)*			2.73	0.38	2.83	0.39	2.32	0.40	2.26	0.40	2.30	0.39
Lvl 2: Random effect: Target Wept *(U1j)*							0.08	0.32	0.14	0.33	0.10	0.32
Lvl 2: Covariance							1.68	0.49	1.72	0.49	1.61	0.48
Lvl 1: Residual *(e0ij)*	6.93	0.30	4.16	0.20	3.93	0.18	3.55	0.18	3.77	0.27	3.54	0.18
Lvl 1: Residual: Target Wept *(e1ij)*									-0.46	0.36		
Fit Statistics												
-2 LL (Number of parameters)	5117.72 (4)		4829.51 (5)		4781.54 (6)		4755.17 (8)		4753.57 (9)		4748.91 (12)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Table A.9. Estimate of effect and model fit parameters for relaxation ratings.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameters	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Fixed Effects												
Intercept *(β0)*	2.09	0.10	2.28	0.30	2.40	0.30	2.27	0.29	2.35	0.30	2.50	0.32
Sad Context	-0.50**	0.14	-0.66*	0.32	-0.65*	0.32	-0.52	0.30	-0.59	0.32	-0.73*	0.35
Joy Context	0.09	0.14	-0.12	0.32	-0.11	0.31	0.03	0.30	-0.10	0.32	-0.08	0.35
Fear Context	-0.56**	0.15	-0.73*	0.32	-0.72*	0.32	-0.59	0.31	-0.62	0.32	-0.98*	0.35
Anger Context	-0.83**	0.14	-0.99**	0.32	-0.98**	0.32	-0.85*	0.30	-0.90**	0.32	-1.18**	0.35
Target Wept					-0.26**	0.08	-0.26**	0.08	-0.27**	0.08	-0.50**	0.17
Target Wept*Sad Context											0.22	0.24
Target Wept*Joy Context											-0.03	0.24
Target Wept*Fear Context											0.57*	0.25
Target Wept*Anger Context											0.45	0.24
Variance Components												
Lvl 2: Random Intercept *(U0j)*			0.72	0.11	0.70	0.11	0.83	0.15	0.71	0.11	0.72	0.11
Lvl 2: Random effect: Target Wept *(U1j)*							-0.15	0.10				
Lvl 2: Covariance							0.05	0.10				
Lvl 1: Residual *(e0ij)*	2.21	0.10	1.49	0.07	1.48	0.07	1.47	0.07	1.96	0.13	1.93	0.13
Lvl 1: Residual: Target Wept *(e1ij)*									-0.95	0.15	-0.93	0.15
Fit Statistics												
-2 LL (Number of parameters)	3893.07 (4)		3694.32 (5)		3683.60 (6)		3680.67 (8)		3640.09 (7)		3630.79 (11)	

Note: * Significant at $p < .05$, ** significant at $p < .001$

Appendix B: ethical Approval (Chapters 3, 4, 5)

University of Portsmouth Faculty of Science

Faculty of Science
University of Portsmouth
St Michael's Building
White Swan Road
PORTSMOUTH
PO1 2DT

Paul.Morris@port.ac.uk
16/03/15

Science Faculty Ethics Committee

Protocol Title: Infra Thermal Imaging Correlates of Emotional Reactions to Films, SFEC 2015-013
Date application received: 02/03/15
Date Reviewed: 16/03/15

FAVOURABLE OPINION – SFEC 2015-013

Dear Dr Morris.

Thank you for your submission for ethical review. Having completed their review, members of the Science Faculty Ethics Committee have reached a Favourable opinion of your proposed research.

Please notify the committee of any substantial amendments to the proposed procedures, send an annual report to the committee regarding study progress and a final study report once the study has concluded. Please send these to ethics-sci@port.ac.uk.

Thank you for your submission and the Committee wishes you well with your study.

Simon Kolstoe – Vice Chair SFEC

CC -
Holly Shawyer – Faculty Administrator

If you would like to offer any feedback on the Science Faculty Ethics Committee process please email ethics-sci@port.ac.uk, to be forwarded to the Chair

Science Faculty Ethics Committee
Science Faculty Office
University of Portsmouth
St Michael's Building
White Swan Road
PORTSMOUTH
PO1 2DT

023 9284 3379
ethics-sci@port.ac.uk

08 March 2017

Mr Marc Baker
Department of Psychology
University of Portsmouth

Marc.Baker@port.ac.uk

FAVOURABLE ETHICAL OPINION – WITH CONDITIONS

Study Title: Does emotional suppression increase or decrease physiological reactivity?

Reference Number: SFEC 2017-015

Date resubmitted: 27 February 2017

Thank you for resubmitting your application to the Science Faculty Ethics Committee (SEFC) for ethical review in accordance with current procedures and for making the requested changes followiing the first SFEC review, and for the clarifications provided.

I am pleased to inform you that SFEC was content to grant a favourable ethical opinion of the above research on the basis described in the submitted documents listed at Annex A, and subject to standard general conditions (*See Annex B)*, and the following specific minor condition(s).

Condition(s)[1]

A. Please note: the way you have chosen to specify your participant group will be understood to be inclusive of any potential trans women participants (please see University Policy 037 Gender Reassignment and Trans Equality Policy, specifically sections 2.2 and 2.3).

Please resubmit an updated application form incorporating the changes as per the above conditions for the final SFEC records on this application.

If you would find it helpful to discuss any of the matters raised above or seek further clarification from a member of the Committee, you are welcome to contact ethics-sci@port.ac.uk who will circulate your queries to SFEC

Please note that the favourable opinion of SFEC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including the University of Portsmouth or supervisor, prior to the start of the study.

Wishing you every success in your research.

Dr John Crossland
Vice Chair Science Faculty Ethics Committee

[1] The favourable opinion given is dependent upon the study adhering to the conditions stated, which are based on the application document(s) submitted. It is appreciated that Principal Investigators may wish to challenge conditions or propose amendments to these. In that case, please consider the favourable opinion suspended, and simply make your case for amending or discarding conditions in writing as you would an application resubmission following ethical review.

Science Faculty Ethics Committee
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023 9284 3379
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Marc Baker
Department of Psychology
University of Portsmouth

Marc.Baker@port.ac.uk

26 February 2018

FAVOURABLE ETHICAL OPINION – FOLLOWING RESUBMISSION

Study Title: The effect of context and tears on judgments of emotions in targets.

Reference Number: SFEC 2018-011

Date Resubmitted: 19 February 2018

Thank you for resubmitting your application to the Science Faculty Ethics Committee (SFEC) for ethical review in accordance with current procedures, for making the requested changes following the first SFEC review, and for the clarifications provided.

I am pleased to inform you that SFEC was content to grant a favourable ethical opinion of the above research on the basis described in the submitted documents listed at Annex A, and subject to standard general conditions (*See Annex B)*.

Please note that the favourable opinion of SFEC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including the University of Portsmouth or supervisor, prior to the start of the study.

Wishing you every success in your research

John C

Dr John Crossland
Vice Chair, Science Faculty Ethics Committee

Annex C: UPR16 Form

FORM UPR16

Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Research Degrees Operational Handbook for more information

UNIVERSITY of PORTSMOUTH

Postgraduate Research Student (PGRS) Information			**Student ID:**	UP660915	
PGRS Name:	Marc Baker				
Department:	Psychology	**First Supervisor:**	Paul Morris		
Start Date: (or progression date for Prof Doc students)		October 2015			
Study Mode and Route:	Part-time ☐	MPhil ☐	MD ☐		
	Full-time ☒	PhD ☒	Professional Doctorate ☐		

Title of Thesis:	Blood, sweat and tears: The production and perception of weeping
Thesis Word Count: (excluding ancillary data)	44302

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

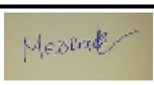
a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES ☒ NO ☐
b) Have all contributions to knowledge been acknowledged?	YES ☒ NO ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES ☒ NO ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES ☒ NO ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES ☒ NO ☐

Candidate Statement:

I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)

Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	SFEC 2018 - 011 SFEC 2017 - 015 SFEC 2015 - 013

If you have *not* submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:

Signed *(PGRS)*:		**Date:** 27.09.2019